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Issued June 29, 1915

NEW SPECIES OF THE HIPPARION GROUP
FROM THE PACIFIC COAST AND GREAT
BASIN PROVINCES OF NORTH AMERICA

BY
JOHN C. MERRIAM

v. 9, 1915-16



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INTRODUCTION

In recent studies of Tertiary faunas occurring in the region west of the Wasatch Range several species of the *Hipparion* type have appeared which seem distinct from any thus far described. As this group has considerable importance in discussion of the West American Tertiary and reference to the species is necessary in papers in which specific descriptions seem not properly included, it is deemed desirable to present a brief statement of the characters of the new forms at this time.

NEOHIPPARION GIDLEYI, n. sp.

Type specimen, an upper molar three, no. 21382. Probably from a stratum just below the coal seam at a mine on the Lawler Ranch, six miles east of Petaluma, California. The formation has been doubtfully referred to the San Pablo Miocene, but may represent a later period.



This species resembles *Neohipparion affine* in its large size and in the high degree of lateral compression of the protocone. The anterior and posterior fossettes (fig. 1) are narrow transversely and the enamel surrounding them shows comparatively few plications. *Neohipparion gidleyi* seems to be distinguished from *N. affine* by its narrow fossettes,

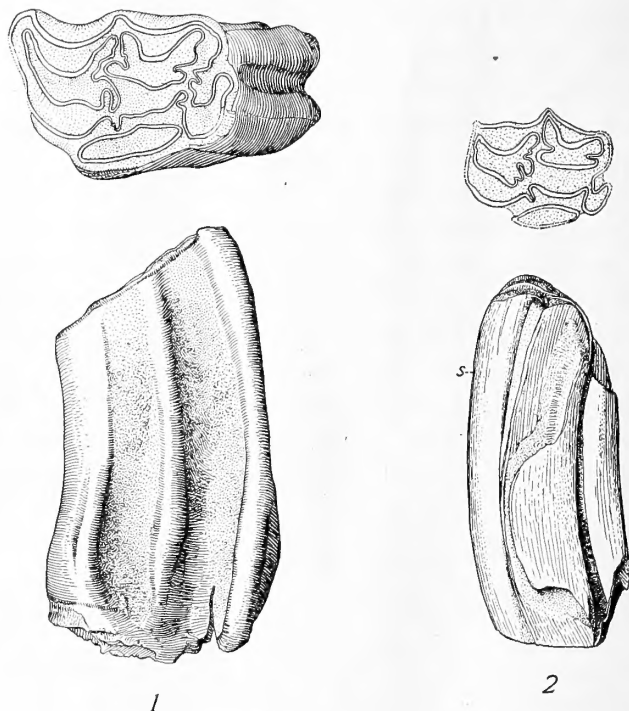


Fig. 1. *Neohipparion gidleyi*, n. sp. M³, no. 21382, type specimen, natural size. Outer and occlusal views. Lawler Ranch, six miles east of Petaluma, California.

Fig. 2. *Neohipparion molle*, n. sp. M³, no. 21370, type specimen, natural size. Inner view and cross-section near base of distal third. s, point at which cross-section is cut. Lower Jacalitos, Pliocene, North Coalinga region, California.

wider protocone, and slightly larger size. The two species are evidently closely related and seem to represent nearly the same stage of evolution.

MEASUREMENTS OF TYPE SPECIMEN

M ³ , anteroposterior diameter	26.7 mm.
M ³ , greatest transverse diameter	20.6
M ³ , anteroposterior diameter of protocone	18.7
M ³ , greatest height of worn crown	55.5

NEOHIPPARION MOLLE, n. sp.

Type specimen, an upper molar, no. 21370, from the Jacalitos formation of the North Coalinga region, California. This species is characterized by length and narrowness of the upper cheek-teeth, simplicity of the enamel borders of the narrow fossettes, and unusually long anteroposterior diameter of the laterally compressed protocone.

Compared with specimens of *Hipparion mohavense* from the Ricardo Pliocene, the tooth crown in *N. molle* is smaller, the fossettes are relatively narrow, and the walls of the fossettes show less plication. The protocone of the Jacalitos species is absolutely wider anteroposteriorly and much narrower transversely.

The form represented by specimen no. 21370 (fig. 2) resembles *Neohipparion montezumae* described by Leidy from Lacaultipan, Hidalgo, Mexico, in general dimensions. In the type specimen of *N. montezumae* the borders of the fossettes are more complicated while the protocone is not as wide anteroposteriorly and is relatively less compressed laterally than in the Coalinga form. Better material of both the Mexican and the Coalinga forms may show closer relationship or even identity of the two. *N. sinclairii* of the Rattlesnake Pliocene in eastern Oregon is of the same general type as *N. montezumae* and *N. molle*.

MEASUREMENTS OF TYPE SPECIMEN

M ³ , anteroposterior diameter	a19.3 mm.
M ³ , transverse diameter	a15.8
M ³ , anteroposterior diameter of protocone	9.4
M ³ , length of crown	48

a, approximate.

NEOHIPPARION LEPTODE, n. sp.

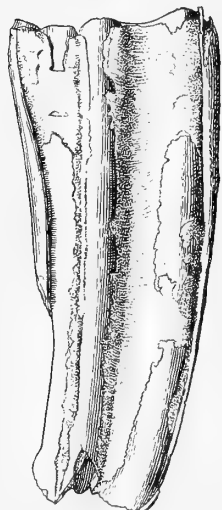
Type specimen, a lower molar, no. 19414, Thousand Creek Beds, Thousand Creek, Nevada. Crown much elongated, slender, relatively straight, well cemented, much compressed laterally. Metaconid-metastylid column long anteroposteriorly, narrow transversely, with wide, flat internal groove. Hypoconid ridge prominent. A strong external protoconid ridge present.

Specimen 19414 (fig. 3) from locality 1101 in the Thousand Creek region resembles in many respects the peculiar *Equus curystylus* described by Cope¹ from the Goodnight? Beds of Paloduro Cañon, Texas. Gidley² considers the horizon at which this fauna was found as upper

¹ Cope, E. D., Geol. Surv. Texas, 3rd Ann. Rep. for 1891, p. 43, pl. 12, figs. 7-8, pl. 20, fig. 6. Issued 1892.

² Gidley, J. W., Bull. Am. Mus. Nat. Hist., vol. 19, p. 632, 1903.

Miocene. *E. eurystylus* is distinguished by extreme narrowness of the lower molar crowns, by the great anteroposterior diameter of the



3

Fig. 3. *Neohipparion leptode*, n. sp. M_2 , no. 19414, type specimen, natural size. Inner and occlusal views, Thousand Creek, Pliocene, Thousand Creek, Nevada.

metaconid-metastylid column and its close appression to the protoconid and hypoconid, and by the presence of an anteroexternal ridge on the protoconid and one on the hypoconid. These characters of *E. eurystylus* appear in no. 19414 from Thousand Creek. The lower molar (M_2) from Thousand Creek is very long and narrow and was heavily cemented. The anteroexternal ridges on the protoconid and hypoconid are strongly developed, as in *E. eurystylus*. As in Cope's species, the external ridge on the hypoconid forms a prominent ridge on the middle of the external face of the crown.

Gidley³ held that Cope's *Equus eurystylus* represented the genus *Hipparion*. While it is true that the anteroexternal ridge of the protoconid and most of the other characters of *E. eurystylus* may appear in milk teeth of *Equus*, Gidley's reference of this form to a group in or near *Hipparion* is well supported.

Specimen no. 19414 from Thousand Creek represents a species in many respects near *Neohipparion eurystyle*? (Cope). The Thousand Creek form is larger and the details of structure are sufficiently different to separate the two, at least, tentatively. It also resembles other American forms of the *Hipparion* group, as *Neohipparion occidentale*, in many characters, but seems not clearly referable to these species. The writer has, therefore, referred the Thousand Creek form tentatively to a distinct species.

MEASUREMENTS

	N. leptode, no. 19414	N. eurystyle
M_2 , greatest anteroposterior diameter	29+ mm.	24
M_2 , transverse diameter	11	10
M_2 , greatest length of crown	66	55
M_2 , anteroposterior diameter of metaconid-metastylid column	14.6	13

³ Gidley, J. W., Bull. Am. Mus. Nat. Hist., vol. 14, p. 126, 1901.

An upper molar⁴ (no. 12581) from the same locality as the lower molar no. 19414 presumably belongs also in or near the *Hipparion* group. This tooth is long and nearly straight. The outer styles are well developed. The mesostyle is of almost even width throughout its whole length. The fossettes are unusually narrow transversely and show a few strong plications. The inner side of the tooth is broken away and it is not possible to determine the characters of the protocone.

MEASUREMENTS OF No. 12581

M ¹ , anteroposterior diameter near base	21.7 mm.
M ¹ , length of slightly worn crown	65.8

HIPPARION PLATYSTYLE, n. sp.

Neohipparion, sp. Merriam, J. C., Univ. Calif. Publ., Bull. Dept. Geol., vol. 7, p. 375, figs. 1a to 1c, 1913.

Type specimen no. 19830, a second upper premolar from the Orinda Pliocene southwest of Mount Diablo, California.

A single tooth obtained from the Orinda beds represents a member of the *Hipparion* group not clearly identical with any known form. The crown is large and well cemented. Though somewhat worn, the form of the fossettes suggests that the crown was never greatly elongated. The small protocone pillar is distinct and is flattened laterally. The fossettes are slightly narrower than in *Hipparion mohavense*. Their enamel walls are moderately crinkled. The outer styles are heavy.

This species most nearly approaches the *Hipparion* forms of the Ricardo fauna. It differs from *H. mohavense* in its more strongly flattened protocone and transversely narrower fossettes. The characters of a single specimen (no. 19478) from the Ricardo fauna approach those of the Orinda specimen, but are not sufficiently near to warrant the conclusion that the two are specifically identical.

MEASUREMENTS OF TYPE SPECIMEN

P ² , greatest anteroposterior diameter	25.8 mm.
P ² , greatest transverse diameter	21.6
P ² , anteroposterior diameter of protocone	8.2

⁴ See Merriam, J. C., Fauna of Virgin Valley and Thousand Creek, Univ. Calif. Publ. Bull. Dept. Geol., vol. 6, p. 263, figs. 32a and 32b, 1911.

HIPPARION CONDONI, n. sp.

In the collections of Professor Thomas Condon, formerly of the University of Oregon, there are two specimens representing a protohippine horse of *Hipparion* type obtained from sedimentary deposits of eastern Washington. The Ellensburg formation, in which these remains were found, has generally been considered as Miocene on the basis of its flora and is commonly correlated with the middle Miocene Mascall formation of the John Day basin in eastern Oregon. The material obtained by Professor Condon is of unusual interest, as it represents the only available mammalian remains from the Ellensburg beds.

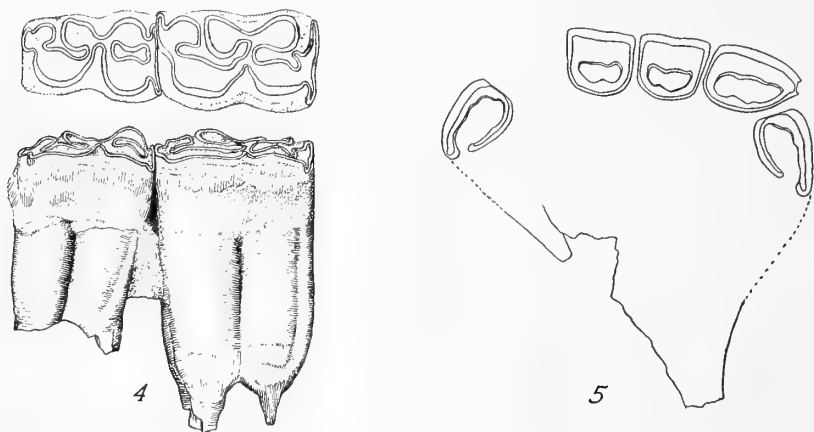


Fig. 4. *Hipparion condoni*, n. sp. P_4 and M_1 , no. 672, Univ. Oreg. Col. Type specimen, natural size. Outer and occlusal views. Ellensburg, Washington.

Fig. 5. *Hipparion condoni?* n. sp. Lower incisors, no. 668, Univ. Oreg. Col. Natural size. Ellensburg, Washington.

Of the two specimens from Ellensburg one (fig. 4) consists of two lower cheek-teeth (no. 672, Univ. Oregon), the other is the anterior portion of a lower jaw with five incisors (fig. 5) (no. 668, Univ. Oregon). Both specimens are partly covered with a matrix consisting of moderately coarse, gray sandstone. It is to be presumed that both specimens are from the same locality.

The lower cheek-teeth represent P_4 and M_1 . The teeth are hypsodont, but appear to be considerably worn. In their present stage of wear, they are not longer than the crowns of some of the advanced *Merychippus* forms from the late Miocene. In an unworn state they

may have attained a length considerably greater than that normal in *Merychippus*. Both crowns are heavily cemented at the summit. The metaconid-metastylid column is longer anteroposteriorly than in any *Merychippus* form known to the writer and corresponds in this diameter to the dimensions of the column in species of the *Hipparion* group. The groove between metaconid and metastylid is wide and flat as in *Hipparion*, rather than narrow and sharp as is commonly the case in *Merychippus*. The parastylid extends inward as far as the inner border of the metaconid. A sharp anteroexternal ridge is developed on the protoconid. The valleys anterior and posterior to the metaconid-metastylid column are comparatively narrow transversely, owing to the large size of the metaconid and metastylid. These valleys correspond approximately in size to those commonly seen in *Hipparion*, and are narrower than those in most species of *Merychippus*. The entoconid is large and unusually full on the anterointernal side. In *Merychippus* this region of the entoconid is commonly not as well developed and may be truncated obliquely. In *Hipparion* this region of the entoconid is commonly full and the anterointernal angle is nearly a right angle, as in the Ellensburg specimen.

The fragment representing the symphysial region of the lower jaw with the incisor teeth (no. 668, Univ. Oregon) is from an animal not differing greatly in dimensions from a number of *Merychippus* specimens from the Upper Miocene of the Barstow region. The incisors are considerably worn, but still show the inner enamel rings of the pits. No satisfactory material representing this portion of the adult dentition of *Merychippus* from the Mascall Miocene is available for a comparison. The teeth are in general larger than those of *Merychippus calamarius* of the Barstow Miocene and are much smaller than incisors of a large *Hipparion* from Ricardo. On the somewhat worn crowns shown in figure 5 the enamel invaginations are clearly shown on all three teeth. The incisors were evidently deeply cupped, but this condition obtains also in the incisors of *Merychippus*, although the infolding of the enamel on the third lower incisor of *Merychippus* is much less strongly marked than on the Ellensburg specimen.

The stage of advance shown by the cheek-teeth of the Ellensburg specimen seems to the writer to be that of *Hipparion* rather than that of *Merychippus*. The form represented in no. 672 does not correspond exactly to any species known to the writer and may be designated as a new species, *Hipparion condoni*. It is distinguished by the size of the crown and by the size and form of the metaconid-metastylid

column. *Hipparion mohavense* of the Ricardo Pliocene seems to be the nearest form among the species west of the Wasatch. The Ellensburg species seems to differ from *H. mohavense* in flatness of the outer walls of the protoconid and hypoconid and in the greater prominence of the anteroexternal angle of the protoconid. Both of these characters may be due to combination of age and individual characters. The habit of the teeth in the Ellensburg specimen suggests that additional material will show more rather than fewer differences separating this form from the *H. mohavense*. *Neohipparion leptode* of the Thousand Creek Pliocene and an allied form from the Rattlesnake Pliocene differ from the Ellensburg specimen in the presence of a very strong anteroexternal ridge on the hypoconid.

Although *Hipparion* has been listed as occurring in the Mascall, Middle Miocene, the writer knows of no occurrence that can certainly be stated to be located within the limits of that formation. Unless it be true that *Hipparion* actually occurs in the Mascall, it seems that the Ellensburg formation may be of considerably later date than the beds containing the typical Mascall fauna of the John Day Valley in eastern Oregon.

MEASUREMENTS

	Hipparion condoni, Ellensburg No. 668 U. O.	Merychippus, Barstow No. 21459	Hipparion mohavense, Ricardo No. 19785
P ₄ , anteroposterior diameter	21 mm.	24.7	23.8
P ₄ , transverse diameter across protoconid	11.1	12	11.9
P ₄ , anteroposterior diameter of metaconid-meta- stylid column	12.6	9.1	14.7
P ₄ , height of worn crown	31	44	32
M ₁ , anteroposterior diameter	17.6	25.4	.....
M ₁ , transverse diameter across protoconid	10.3	10.1	.....
M ₁ , anteroposterior diameter of metaconid-meta- stylid column	11.2	9.9	.....
	Hipparion, Ellensburg, No. 672 U. O.	Merychippus, Barstow No. 21776	
I ₁ , anteroposterior diameter	8.3	7.7	.....
I ₁ , transverse diameter	9.3	.....	.....
I ₂ , anteroposterior diameter	8.3	7.7	.....
I ₂ , transverse diameter	12.1	6.5
I ₃ , anteroposterior diameter	7.4	5.7
I ₃ , transverse diameter	12	5.9

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THE OCCURRENCE OF OLIGOCENE IN THE
CONTRA COSTA HILLS OF MIDDLE
CALIFORNIA

BY

BRUCE L. CLARK



UNIVERSITY OF CALIFORNIA PRESS
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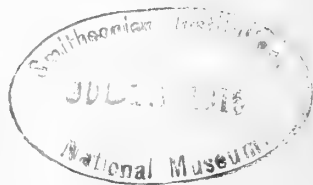
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THE OCCURRENCE OF OLIGOCENE IN THE CONTRA COSTA HILLS OF MIDDLE CALIFORNIA

BY

BRUCE L. CLARK



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INTRODUCTION

Heretofore only two marine stratigraphic groups, the Monterey and the San Pablo, have been recognized in Contra Costa County above the Tejon (Upper Eocene). In the vicinity of San Pablo Bay the Monterey Group of Professor A. C. Lawson has a thickness of over five thousand feet, consisting of nine formations, five of sandstone and four of shale. In the past, three faunal zones have been recognized in this group; the lowest was described by Dr. J. C. Merriam as the *Agasoma gravidum* zone,^{1a} the middle will be referred to here as the *Arca montereyana* zone.¹ The upper zone is known as the *Scutella breweriana* zone.

^{1a} Merriam, J. C., Univ. Calif. Publ. Bull. Dept. Geol., vol. 3, no. 16, p. 378, 1904.

¹ *Arca montereyana* Osmont is possibly the same as *Arca devincta* Conrad. If this determination should prove correct, the horizon should be known as the *Arca devincta* zone.

Recently discovered stratigraphic and palaeontologic evidence indicates that the *Agasoma gravidum* zone belongs to a distinct period of deposition, and that the time-break represented by an unconformity between it and the *Arca montereyana* beds above is apparently a large one. The fauna of the *Agasoma gravidum* zone is correlated by the writer with a part of the Astoria series, as described by Dr. Ralph Arnold and Mr. Harold Hannibal.²

It is only a few years since a marine Oligocene fauna was first recognized on the Pacific Coast by Dr. W. H. Dall in a paper by J. S. Diller entitled "A Geological Reconnaissance of Northwestern Oregon."³ The following year Dall,⁴ in a correlation table of the Tertiary horizons of North America, again placed a part of the Astoria shale of Oregon in the Oligocene.

It was nearly ten years later before attention was called to marine Oligocene beds in California. In 1906 Dr. Ralph Arnold⁵ listed a fauna from a formation, which he named the San Lorenzo and which he believed to be of Oligocene age. In 1908 Arnold published the descriptions of the new species obtained from the San Lorenzo Formation and again referred it to the Oligocene.⁶ In the *Santa Cruz folio*⁷ a definite description of the lithology and stratigraphy of the San Lorenzo is given. The final conclusion was that there is no evidence of a stratigraphic break in the Santa Cruz Mountains between the Oligocene and the Miocene. It was believed that certain beds, designated as Transitional Oligocene-Miocene, contained a fauna which was transitional between the Oligocene and the Miocene.

The first attempt to separate the faunas of the Lower Miocene and Oligocene in Oregon was by Dr. W. H. Dall.⁸ Dall at that time recognized the inadequacy of his list and the probability of the mixture of his faunas.

² Arnold, Ralph, and Hannibal, Harold, The marine Tertiary stratigraphy of the North Pacific Coast of America, *Proc. Amer. Phil. Soc.*, vol. 52, no. 212, November-December, 1913.

³ Diller, J. S., 17th Ann. Rept. U. S. G. S., pt. L, p. 464, 1895.

⁴ Dall, W. H., A table of North American Tertiary horizons correlated with one another and with those of Western Europe, with annotations, 18th Ann. Rept. U. S. G. S., pt. II, p. 334, 1896-97.

⁵ Arnold, Ralph, Prof. Paper U. S. Geol. Surv., no. 47, pp. 16, 17, 1906.

⁶ Arnold, Ralph, Descriptions of new Cretaceous and Tertiary fossils from the Santa Cruz Mountains, California, *Proc. U. S. Nat. Mus.*, vol. 34, no. 617, pp. 345-385.

⁷ Branner, J. C., Newsom, J. F., Arnold, Ralph, *Santa Cruz Folio*, U. S. Geol. Surv., no. 163, p. 4, 1909.

⁸ Dall, W. H., The Miocene of Coos Bay, Oregon, Prof. Paper U. S. Geol. Surv. no. 59, p. 11, 1909.

Two important papers published during the last two years have added considerably to our knowledge of the Tertiary faunas of the North Pacific Coast. The first of these was by Dr. C. E. Weaver.⁹ The second paper, by Arnold and Hannibal,¹⁰ undertakes a broader and more general correlation. Beds which are placed in the Oligocene are referred to the Astoria series, which is divided into three formations—the San Lorenzo, Seattle, and Twin River. These formational names are apparently not used in the lithologic sense but in the faunal. The lowest of the three faunas is recognized as being equivalent to the San Lorenzo of the Santa Cruz Quadrangle, California. Beds which are called the Monterey are said to overlies the Astoria series. An unconformity is inferred between the Monterey and the Astoria series, but no definite description is given.

Weaver in describing the Oligocene and Miocene horizons did not recognize any of the older and more general names. Beds, the faunas of which are equivalent in part at least to the Astoria series of Arnold and Hannibal, are called by him the Lincoln and Blakeley formations. The former is referred to the Oligocene, the latter to the Miocene. Weaver apparently uses the term “formation” in a lithologic sense.

In a recent paper, Chester W. Washburne¹¹ gives a brief description of the sedimentary formations in northwestern Oregon. According to Washburne, no evidence has been obtained in that region which indicates a stratigraphic break between beds regarded as Oligocene and those of upper Eocene age. It is stated also that there is no reason, stratigraphic or lithologic, for the separation of these Oligocene beds from beds which are considered to be of Miocene age. The evidence for making the division was entirely palaeontologic, being based upon the work of Dr. W. H. Dall. It is stated that Arnold and Hannibal do not agree with this division, since they place the lower part of the Miocene as recognized by Dall in the vicinity of Astoria, Oregon, as a part of the Oligocene.

In the Contra Costa hills the beds, which in this paper are referred to the Oligocene, have heretofore been included in the Miocene and considered to be a part of the Monterey Group. However, the distinctness of this fauna has long been recognized. In 1904 Dr. J. C. Merriam¹² notes that the fauna of the beds referred to the Monterey

⁹ Weaver, C. E., A preliminary report on the Tertiary palaeontology of Western Washington, Washington Geol. Surv. Bull., no. 15, pp. 1-80, 1912.

¹⁰ Arnold, Ralph, and Hannibal, Harold, *op. cit.*

¹¹ Washburne, Chester W., Reconnaissance of the geology and oil prospects of Northwestern Oregon, U. S. G. S. Bull., 590, pp. 1-110, 1914.

¹² Merriam, J. C., A note on the fauna of the Lower Miocene in California, Univ. Calif. Publ., Bull. Dept. Geol., vol. 3, no. 16, p. 378, 1904.

is separable into at least two zones exclusive of the shale facies. The following statement is made:

The fauna of the lower division is much more characteristic than the upper; that is to say, it differs more decidedly from that of the beds immediately above and below it. . . . The most characteristic species are *Agasoma grvida*, *Dosinia mathewsoni*, *Chione mathewsoni*, and *Mytilus mathewsoni*. . . . The lower fauna is recognized at many places in Contra Costa County, and always near the base of the series. This faunal division might appropriately be called the zone of *Agasoma grvida*.

In the San Francisco Folio,¹³ which was published very recently by Professor A. C. Lawson, the beds containing the fauna of the *Agasoma gravidum* zone, as defined by Dr. J. C. Merriam, are included in the Miocene as a part of the Monterey group. For this the writer is in part responsible.

AGASOMA GRAVIDUM BEDS IN THE VICINITY OF THE TOWN OF WALNUT CREEK

The unconformity between the *Agasoma gravidum* beds and the *Arca montereyana* beds in certain localities in Contra Costa County is in the Sobrante sandstone, the basal member of the Monterey group of Lawson. It is best seen in the section of the Monterey a little to the south of the town of Walnut Creek and only a few miles west of Mount Diablo. Here the *Agasoma gravidum* beds outcrop on two sides of a southeasterly plunging, tightly appressed syncline, resting upon the Tejon (Eocene) and being overlain unconformably by beds containing the fauna of the *Arca montereyana* zone.¹⁴

On the west side of the syncline, to the southwest of the town of Walnut Creek and on the west side of San Ramon Valley, the beds of the *Agasoma gravidum* zone are about 525 feet in thickness. They consist for the most part of a fine gray tuffaceous sandstone, which in some localities has a blueish cast. A little above the middle of the section there is a thin bed of a siliceous gray shale. Excellent exposures of these beds may be seen about two miles to the south of the town of Walnut Creek.

Relation to Tejon.—No heavy conglomerates were found in this section at the base of the *Agasoma gravidum* beds. The exact line of contact between it and the Tejon (Eocene) is uncertain. So far, no direct evidence has been obtained in any of the sections studied

¹³ San Francisco Folio, U. S. Geol. Surv., no. 193, 1914.

¹⁴ See Geologic Map of Concord Quadrangle, S. F. Folio, U. S. Geol. Surv., no. 193, 1914.

of a stratigraphic break between the Tejon and the *Agasoma gravidum* beds. However, in almost every section a typical Tejon fauna was found not very far below beds containing the *Agasoma gravidum* fauna. The great difference between these two faunas leaves very little doubt as to the presence of a large break.

Relation to Arca montereyana Zone.—The *Agasoma gravidum* beds, just described, are overlain unconformably by beds containing an almost entirely different fauna. These represent the base of the *Arca montereyana* zone, and contain the following species:

<i>Arca montereyana</i> Osmont	<i>Ostrea titan</i> Conrad
<i>Marcia oregonensis</i> Conrad	<i>Agasoma barkerianum</i> Anderson
<i>Mulinia densata</i> Conrad	<i>Crepidula princeps</i> Conrad
<i>Panope estrellana</i> Conrad	<i>Fusus stanfordensis</i> Arnold
<i>Pecten</i> , cf. <i>bowersi</i> Arnold	

A number of new species were found at this horizon. Of those listed above, the only one which has been found in the *Agasoma gravidum* beds is *Panope estrellanus*.

The *Arca montereyana* beds in this section have an estimated thickness of about 800 feet. The basal 100 feet consists of coarse sandstone in which cross-bedding is very common, together with lenses of conglomerate and shale. This is followed by about 100 feet of pearl-gray shale, above which the beds consist for the most part of a fine gray sandstone.

The line of contact between the *Arca montereyana* beds and the *Agasoma gravidum* beds is marked by conglomerate and coarse sandstone. The conglomerate is lenticular and, in some localities, has a thickness of from ten to fifteen feet; in other localities it may be almost entirely absent. The boulders and pebbles found in it were derived from many sources; both igneous and sedimentary rocks are present.

The evidence in this section for an unconformity between the *Arca montereyana* beds and the *Agasoma gravidum* beds is as follows: (1) It is suggested by lithology; conglomerates and coarse sandstone occur along a line of contact, below which there is a sudden change to a fine sandstone. (2) A contact with irregularities of considerable size has been observed between these two horizons; in certain localities the *Agasoma gravidum* beds vary in thickness along the strike, due apparently to erosion; the *Arca montereyana* beds have long been known to rest locally upon the Eocene. (3) Fossiliferous boulders

which contain characteristic species of the *Agasoma gravidum* beds, are found in the conglomerates at the base of the *Arca montereyana* beds. At some localities these boulders are so abundant that one, in collecting from the matrix of the conglomerate, must be careful not to gather a mixture of the upper and lower faunas. The writer has collected ten or more species of the *Agasoma gravidum* fauna from boulders in this basal conglomerate and undoubtedly a much larger number could be obtained. Many boulders are quite angular and were over a foot in diameter and apparently they could not have been transported far. It seems possible therefore that they were derived from cliffs in the vicinity of this beach during Monterey time.

FAUNAL RELATIONSHIP OF AGASOMA GRAVIDUM ZONE TO ARCA MONTEREYANA ZONE

The best evidence for an important hiatus between the *Agasoma gravidum* beds and the *Arca montereyana* beds is palaeontological. At present ninety molluscan species are known from the *Agasoma gravidum* beds; of these thirty-one, or over 40 per cent, of the determinable species are new. Over sixty determinable species are known from the *Arca montereyana* zone of Contra Costa County; of these only twelve have been found in the *Agasoma gravidum* zone. None of these twelve species common to the two zones are forms that are generally considered to be good horizon determiners. Fifty-five of the determinable species of the *Agasoma gravidum* zone have not been found in the *Arca montereyana* zone, and there is nearly an equal number in the upper of the two zones which have not been found in the lower.

LIST OF SPECIES FROM AGASOMA GRAVIDUM ZONE OF CONTRA COSTA COUNTY, CALIFORNIA

Pelecypoda

Arca, n. sp., A.
Arca, n. sp., B.
Acila, n. sp.
Amiantis, n. sp.
Cardium lorenzanum Arnold
Cardium vaqueroesensis Arnold
Cardium, n. sp.
Chione, n. sp., A.
Chione, n. sp., B.
Chione, n. sp., C.
Diplodonta, n. sp.
Donax, sp. indt.
Dosinia whitneyi (Gabb)
Leda, n. sp.

Leda, sp.?
Macrocallista, n. sp.
Macrocallista cf. *vespertina*
 (Conrad)
Macrocallista? *mathewsonii*
 (Gabb)
Mya, n. sp.
Mytilus mathewsonii Gabb
Mytilus, sp.?
Nucula, n. sp., A.
Nucula, n. sp., B.
Panope estrellana, Conrad
Periploma, sp.?
Pecten, n. sp.
Pecten peckhami Conrad

Pecten, sp.?	Molopophorus biplicatus Gabb
Phacoides acutilineatus (Conrad)	Molopophorus gabbi Dall
Pitaria, n. sp.	Murex (Ocinebra), n. sp.
Psammobia, sp.	Natica (Neverita) recluziana
Solen, n. sp. aff. parallelus Gabb	Petit
Solen curtus Conrad	Natica (Neverita), cf. callosa
Spisula occidentalis (Gabb)	Gabb
Spisula ramonensis Packard MS.	Natica, n. sp.
Spisula, sp.?	Natica (Euspira), n. sp.
Tellina oregonensis Conrad	Natica (Neverita), n. sp.
Tellina, sp.?	Neptunea recurva Gabb
Tellina, n. sp.	Olivella, n. sp.
Tellina lorenzoensis Arnold	Olivella, cf. pedroana Conrad
Thracia condoni, Dall	Phalium, n. sp.
Thracia, n. sp.	Sinum scopulosum (Conrad)
Yoldia, n. sp.	Strepsidura, sp.
Yoldia, sp.?	Thais, n. sp.
Gasteropoda	Turbinella, sp.?
Agasoma acuminatum Anderson	Turritella porterensis Weaver
and Martin	Turris, n. sp., A.
Agasoma gravidum (Gabb)	Turris, n. sp., B.
Ancillaria fishi Gabb	Turris, sp.?
Bursa mathewsoni (Gabb)	Scaphopoda
Calliostoma, n. sp.	Dentalium, n. sp.
Columbella, n. sp.	Dentalium petricola Conrad
Chrysodomus, n. sp.	Dentalium, cf. stramineum Gabb
Chrysodomus, n. sp.	Cephalopoda
Crepidula praerupta Conrad	Aturia, sp.?
Cerithium, n. sp.	Crustacea
Calyptrea excentrica (Gabb)	Balanus, sp.?
Calyptrea radiata (Lamarck)	Anthozoa
Cancellaria condoni Anderson	Siderastrea, n. sp.
Epitonium, n. sp.	Amphineura
Epitonium, sp.?	One anterior plate of chiton
Fusinus (Priscofusus) hecoxi	Echinodermata
Arnold	Linthia californica Weaver
Haminea, sp.?	
Mioplenia, sp.?	

RELATION OF THE AGASOMA GRAVIDUM ZONE TO THE LOWER MIOCENE OF SOUTHERN CALIFORNIA

Before considering the problem of the correlation of the *Agasoma gravidum* zone, it is desirable to outline the classification of the marine Neocene of the Californian area.

The Neocene of California is divisible into two parts by a stratigraphic break, which occurs somewhere between Middle and Upper Miocene. This interruption has been referred to by Arnold as "the most widespread and important period of diastrophism in the Tertiary history of the Pacific Coast. . . . Its effects are visible from Puget Sound to Southern California; it is marked by much readjustment, by local faulting and folding, as by general movements of elevation and subsidence."¹⁵

¹⁵ Arnold, Ralph, *Environment of the Tertiary Faunas of the Pacific Coast*, in Willis and Salisbury, *Outline of Geologic History*, p. 241, 1910.

For the purposes of this paper it will not be necessary to consider the beds, which are above the stratigraphic break to which reference has just been made. The beds below this unconformity (usually designated as Lower Miocene) are known by various local names along the Pacific Coast. It is still a question whether they form one, two, or possibly more distinct epochs of deposition. In California two faunal zones have been recognized in these beds, both of which represent a littoral facies of deposition. Besides these, there is a fauna obtained from the diatomaceous shales of the Coast Ranges usually known as the Monterey shale. This latter fauna has generally been considered to be contemporaneous with the two littoral faunal zones. However, in a recent paper Mr. F. M. Anderson¹⁶ has expressed the belief that the fauna from the Monterey shales of the Coast Ranges belongs to a distinct and later period of deposition than either of the two littoral faunas mentioned above. The lower of the two littoral faunas has been generally known as the *Turritella inezana* zone; the upper as the *Turritella ocoyana* zone. Beds containing the fauna of the lower zone have usually been called Vaqueros; beds of the upper zone have been referred to as Vaqueros, Monterey, and Temblor.

The *Agasoma gravidum* beds of middle California were first provisionally considered by Dr. J. C. Merriam¹⁷ to be near the age of the *Turritella ocoyana* beds, referred to above. With the data now at hand, it would appear that the faunas of the *Turritella ocoyana* and the *Turritella inezana* zones are more closely related than has heretofore been supposed; that though possibly there may be a stratigraphic break between them, as has been reported in several localities, the faunal evidence would seem to show that the time-break was probably not a large one. There is apparently a much greater difference between the fauna of the *Agasoma gravidum* zone and that of the *Turritella inezana* zone than there is between the fauna of the latter and that of the *Turritella ocoyana* zone. It is certain that the fauna of the *Agasoma gravidum* zone of Contra Costa County belongs to an older horizon than the *Turritella ocoyana* zone, and it appears to the writer to be older than the *Turritella inezana* zone.

The fauna of the *Arca montereyana* zone of Contra Costa County is as old as that of the *Turritella ocoyana* zone and possibly older.

¹⁶ Anderson, F. M., and Martin, Bruce, Neocene record in the Temblor Basin, California, and Neocene deposits of the San Juan District, San Luis Obispo County, Proc. Cal. Acad. Sci., 4th ser., vol. 4, pp. 15-112, pls. 1-10, 1915.

¹⁷ Merriam, J. C., Fauna of the Lower Miocene in California, Univ. Calif. Publ., Bull. Dept. Geol., vol. 3, p. 380, 1904.

It contains many of the Lower Miocene species, a number of which in the southern part of the state are found in both the *Turritella ocoyana* and *Turritella inezana* zones.

EVIDENCE SUGGESTING CORRELATION OF THE FAUNA OF THE
AGASOMA GRAVIDUM ZONE OF CONTRA COSTA COUNTY,
CALIFORNIA, WITH THAT OF THE OLIGOCENE OF
OREGON AND WASHINGTON

Accumulating evidence seems to show that there is a faunal break in Oregon and Washington between the Oligocene and Lower Miocene which is as great as that in California. The distinctness of the faunas of these two horizons will be more easily shown when a larger percentage of the known species have been described.

The writer has had the opportunity of studying large collections at the California Academy of Sciences, which were obtained by Bruce Martin from many of the Oligocene and Miocene localities listed by Arnold and Hannibal, Dall, and Weaver. It was by means of these collections that data were obtained for correlating the *Agasoma gravidum* beds with the Oligocene of Oregon and Washington.

Two important localities from which Mr. Martin obtained fairly large collections of very well preserved fossils are from the bluffs near the town of Pittsburg, Columbia County, Oregon, and on Lincoln Creek near the boundary line of Lewis and Thurston counties, Washington. The beds at the Pittsburg locality are classed as Eocene by Dr. W. H. Dall.¹⁸ It was here that the types *Macrocallista pittsburgensis* (Dall) and *Acila shumardi* Dall were obtained. The collection obtained by Mr. Martin at this locality shows conclusively that this fauna cannot be classed as Tejon (Upper Eocene), but is equivalent to what Dall recognizes elsewhere as being Oligocene. The Lincoln Creek locality is the type locality of Dr. C. E. Weaver's Lincoln Formation,¹⁹ which he considers to be Oligocene and from which he lists a number of Eocene species.

The species in the collection of the California Academy of Sciences from the Pittsburg and Lincoln localities are listed below. In the table following are indicated the species common to either of these localities and the *Agasoma gravidum* beds of Contra Costa County and the San Lorenzo of Santa Cruz County.

¹⁸ Dall, W. H., Trans. Wagner Free Inst. Sci., vol. 3, pt. 6, p. 1253, pl. 36, fig. 32, pl. 43, fig. 15, 1903; Washburne, C. W., Reconnaissance of the geology and oil prospects of Northwestern Oregon, U. S. G. S. Bull., no. 596, p. 31, 1914.

¹⁹ Weaver, C. E., A preliminary report on the Tertiary palaeontology of Western Washington, Washington Geol. Surv. Bull., no. 15, pp. 15-16, 1912.

	Pittsburg	Lincoln	Contra Costa Hills	San Lorenzo
PELECYPODA				
<i>Acila shumardi</i> Dall	×	×
<i>Cardium lorenzanum</i> Arnold	×	×	×
<i>Crassatella washingtonensis</i> Weaver	×
<i>Crenella porterensis</i> Weaver	×
<i>Diplodonta</i> , n. sp.	×	×
<i>Glycimeris</i> , n. sp.	×
<i>Leda impressa</i> Conrad	×	×	×
<i>Malletia chehalisensis</i> Arnold	×	×
<i>Macrocallista pittsburgensis</i> Arnold	×
<i>Panope estrellana</i> Conrad	×	×
<i>Phacoides acutilineatus</i> (Conrad)	×	×
<i>Pitaria</i> , n. sp.	×	×
<i>Spisula ramonensis</i> Packard	×	×
<i>Solen curtus</i> Conrad	×	×
<i>Solen</i> , n. sp., aff. <i>parallelus</i> Gabb	×	×
<i>Tellina oregonensis</i> Conrad	×	×
<i>Thracia condoni</i> Dall	×	×
GASTROPODA				
<i>Agasoma gravidum</i> (Gabb)	×	×
<i>Aneillaria fishi</i> Gabb	×	×
<i>Calyptrea excentrica</i> (Gabb)	×	×	×	×
<i>Fusinus</i> (<i>Priscofus</i>) <i>hecoxi</i> Arnold	×	×	×	×
<i>Hemifusus washingtoniana</i> Weaver	×	×
<i>Molopophorus</i> , n. sp.	×
<i>Molopophorus gabbi</i> Dall	×	×
<i>Morio</i> , aff. <i>tuberculata</i> Gabb	×
<i>Natica reclusiana</i> Petit	×	×	×
<i>Natica oregonensis</i> Conrad	×	×	×
<i>Pleurotoma perissolaxoides</i> Arnold	×	×
<i>Scaphander</i> , cf. <i>oregonensis</i> Dall	×
<i>Strepsidura californica</i> Arnold	×	×
<i>Turris</i> , n. sp. A.	×	×
<i>Turris</i> , n. sp. B.	×	×	×
<i>Turritella porterensis</i> Weaver	×	×	×

As shown in the above list, sixteen species out of a fauna of twenty-one obtained from the beds at Pittsburg are common to the *Agasoma gravidum* zone of Contra Costa County. Out of a fauna of eighteen species obtained from the beds of the Lincoln Creek locality eight are common to the *Agasoma gravidum* zone of Contra Costa County. A noticeable feature of the group of species common to the *Agasoma gravidum* zone and these northern localities is that a large proportion of them are fairly highly ornamented types, belonging to genera the

species of which are generally considered to be especially good horizon determiners, such as *Agasoma*, *Molopophorus*, *Priscofusus*, and *Turritella*.

The Oligocene fauna, as found at Pittsburg, Oregon, and Lincoln Creek, Washington, is fairly well represented throughout the western part of Washington and the northwestern part of Oregon. This fauna is everywhere very distinct both from that of the Eocene and from that of the typical Miocene. The following conclusions are based upon a large number of localities in Oregon and Washington, from which Mr. Martin obtained representative faunas of the Oligocene and Miocene formations.

Nearly half of the determinable species from the *Agasoma gravidum* zone as known in Contra Costa County, California, are found in the Astoria series, as recognized by Arnold and Hannibal in Oregon and Washington, which includes the Pittsburg beds and the Lincoln Formation referred to above. The following are some of the described species which are common to the two. (Those species marked with an asterisk are believed to be characteristic of the Oligocene.)

<i>Cardium lorenzanum</i> Arnold	* <i>Agasoma acuminatum</i> Martin and Anderson
* <i>Macrocallista mathewsonii</i> (Gabb)	* <i>Ancillaria fishi</i> Gabb
* <i>Mytilus mathewsonii</i> (Gabb)	* <i>Bursa mathewsoni</i> (Gabb)
<i>Panope estrellana</i> (Conrad)	<i>Calyptraea excentrica</i> (Gabb)
<i>Pecten peckhami</i> Gabb	* <i>Ficus pyriformis</i> Gabb
<i>Phacoides acutilineatus</i> (Conrad)	* <i>Molopophorus biplicatus</i> Gabb
<i>Solen curtus</i> Conrad	* <i>Molopophorus gabbi</i> Dall
* <i>Tellina lorenzanum</i> Arnold	* <i>Fusinus</i> (<i>Priscofusus</i>) <i>hecoxi</i> (Arnold)
<i>Tellina oregonensis</i> Conrad	* <i>Turritella porterensis</i> Weaver
* <i>Agasoma gravidum</i> (Gabb)	

Besides the species listed above, a number of new species have been found which are common to the two horizons. Some of these are *Cardium*, n. sp., *Chione*, n. sp., *Pitaria*, n. sp., *Pecten*, n. sp., *Solen*, n. sp., *Spisula*, n. sp., *Solen*, n. sp. aff. *parallelus* Gabb, *Natica*, n. sp., *Turris*, n. sp. A., *Turris*, n. sp. B., *Dentalium*, n. sp.

Of the species which are common to the *Agasoma gravidum* zone of Contra Costa County, California, and the Oligocene of Oregon and Washington, *Cardium lorenzanum*, *Tellina lorenzanum*, and *Fusinus hecoxi* were first described from the San Lorenzo of the Santa Cruz Quadrangle. *Turritella porterensis* was described from the Porter beds of Washington, which beds Arnold correlates with his San Lorenzo and which are placed by Weaver in the Blakeley Formation. *Molopophorus gabbi* was described by Dall from the Astoria beds of Oregon.

The following species, which are believed to be characteristic of the Oligocene and which are very common in the Oligocene in the north, were originally described from the *Agasoma gravidum* beds of Contra Costa County: *Macrocallista? mathewsonii* (Gabb), *Mytilus mathewsonii* Gabb, *Agasoma gravidum* (Gabb), *Ancillaria fishi* Gabb, *Bursa mathewsoni* (Gabb), *Ficus pyruformis* Gabb, *Molopophorus biplicatus* Gabb. Some of these, *Macrocallista? mathewsonii*, *Mytilus mathewsonii*, *Agasoma gravidum*, *Molopophorus biplicatus*, have been reported in the Lower Miocene (*Turritella ocoyana* and *Turritella inezana* zones). The writer has had an opportunity to examine most of the forms determined as these species from the Miocene, and with possibly one or two exceptions these determinations are believed to be wrong.

Much remains to be done before the faunal zones of the marine Oligocene of the west coast are definitely outlined. Arnold and Hannibal²⁰ have recognized three faunal zones in their Astoria series—the San Lorenzo, the Seattle, and the Twin River formations. The San Lorenzo horizon is correlated by them with the San Lorenzo formation of the Santa Cruz Mountains in California. Nearly all of the new species originally described by Arnold from the San Lorenzo of California have been found in the San Lorenzo of Oregon and Washington. A number of these are also found in the Seattle beds.

The fauna of the Lincoln Formation described by Professor C. E. Weaver is considered by Arnold and Hannibal as the equivalent of the San Lorenzo horizon. The Porter beds in the vicinity of the town of Porter, originally referred to the Miocene by Weaver, are at least in part Oligocene and apparently belong to the San Lorenzo horizon.

Much remains to be done before the faunal zones of the marine Oligocene of the west coast are definitely outlined. For this reason only a very general statement as to the probable position of the *Agasoma gravidum* fauna in the Oligocene section of the west coast will be made. The fauna of the *Agasoma gravidum* zone is possibly somewhat younger than that of the San Lorenzo. Certain species which are found in the Santa Cruz Mountains and in Oregon and Washington, and which are thought to be characteristic of the San Lorenzo horizon, have not been found in the *Agasoma gravidum* beds. Also the lack in the fauna of the *Agasoma gravidum* beds of certain Eocene species found in the San Lorenzo horizon of Oregon and Washington, is quite noticeable. However, this evidence is negative,

²⁰ Arnold, Ralph, and Hannibal, Harold, *op. cit.*, p. 579.

and when a larger fauna is obtained from the type section of the San Lorenzo it is not at all improbable that these beds may be found to be equivalent, in part at least, to the *Agasoma gravidum* beds of Contra Costa County.

SUMMARY

1. In Contra Costa County, California, beds containing the fauna of the *Agasoma gravidum* zone are unconformably below those containing the fauna of the *Arca montereyana* zone. This unconformity is believed to be more than local and represents the line of division between Miocene and Oligocene.

2. In California there is apparently a very marked difference between the *Agasoma gravidum* fauna and that of the middle and lower Miocene. The faunal break between the Oligocene and Miocene in Oregon and Washington appears to be as great as in California.

3. The fauna of the *Agasoma gravidum* zone of Contra Costa County may possibly belong to a higher horizon in the Oligocene than the typical San Lorenzo. The evidence for this statement is chiefly negative; future work may show a closer relationship to the San Lorenzo.

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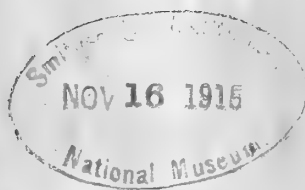
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Issued November 6, 1915

THE EPIGENE PROFILES OF THE DESERT

BY

ANDREW C. LAWSON



UNIVERSITY OF CALIFORNIA PRESS
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RAINGLESS REGIONS

In a rainless region an uplifted land-mass, an orogenic block, is subject to degradation by:

1. The process of mechanical disintegration at the surface due to differential dilations and contractions under varying temperatures; (2) the gravitational transportation of the fragments thus detached from higher to lower levels; (3) the transportation by the wind of such of these detached fragments as may be small enough to be removed; (4) the corrasive action of wind-moved detritus and the removal of the products of such corrasion by the wind.

The relative efficacy of these processes in a purely *a priori* discussion depends altogether upon what assumptions are made. If, for

* Read before Geological Society of America at the Berkeley Meeting, Aug., 1915.

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example, we assume that our orogenic block is composed of fine-grained incoherent rock and assume further the prevalence of powerful winds, then the last two of these processes might well be most important agencies of degradation. But if we assume that our orogenic block is composed of coherent, hard, elastic rock, then the products of mechanical disintegration would in general be of such a size as to be but slightly affected by the wind, and the first two processes would be almost the only agencies concerned in the degradation of the uplifted mass. It is the latter case, the effect of mechanical disintegration and gravitational transportation, that I desire here to discuss briefly as an introduction to the consideration of more complex conditions in the later part of the paper. For the purpose of simplifying the discussion I will further assume that the mountain is lithologically and structurally homogeneous.

Under the conditions assumed, our uplifted block may have initial slopes which are (1) less than the slope of repose for loose material, or, (2) greater than the slope of repose. The gentler slopes will remain unaltered throughout the persistence of the rainless climate. The surface will of course be at first subject to mechanical disintegration, but in the absence of any transporting agency the products of disintegration will encumber the firm rock and protect it from further attack. There can be no change of slope due to degradation. The steeper slopes, on the other hand, cannot retain the fragments shed by disintegration, and these lodge at the base of the slope in the form of talus. The slope of the talus thus becomes the limiting slope of all mountain facets evolved under such conditions. If we suppose a steeper slope to come into existence, as for example by repeated faulting, the disintegration of the surface and the direct action of gravity will give rise to a talus at its base. As the latter grows it maintains the constant slope of repose of loose material; but its upper edge encroaches upon higher and higher parts of the battered scarp. While this encroachment is in progress the batter of the scarp approaches the slope of the talus; and when the two coincide the combined slope of the battered scarp and talus becomes the final, unchanging mountain front. The talus ceases to grow and the rock slope above ceases to diminish, the loose fragments on both lying at the limiting angle at which gravity will move them.

During the encroachment of the talus upon the battered scarp the latter has been reduced in acclivity by more active recession in the

upper than in the lower part.¹ The recession has been progressive with the growth of the talus, and the portion of the battered scarp which becomes buried is therefore a parabolic curve, the volume of the talus being assumed equal to the volume of the rock in place, while the portion which remains above the talus maintains a straight slope. The development of the final combined facet from the initial scarp is shown in the diagram, figure 1.

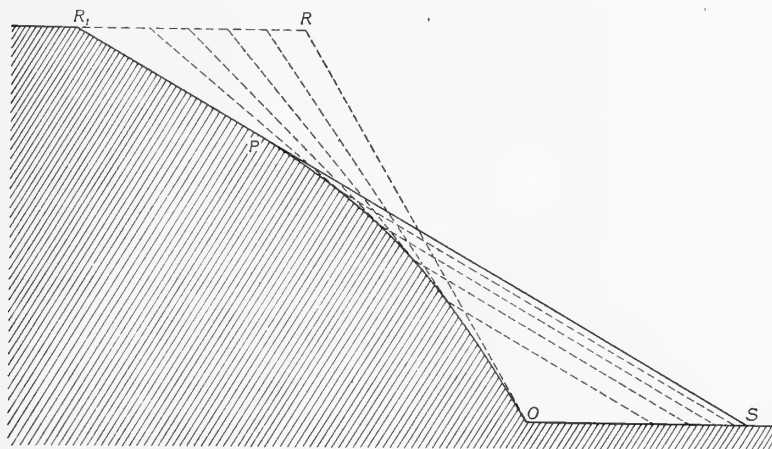


Figure 1.—Under rainless conditions a mountain face OR would be reduced to OPR , the lower curved portion of which OP would be buried in talus OSP . The combined rock and talus slope SPR , is the unchanging profile under the assumed conditions.

In the foregoing statement it is of course not implied that the talus profile is found only in rainless climates; it may and does occur under humid conditions, but here it is a temporary phase of the geomorphic evolution, whereas under rainless conditions it is a permanent and characteristic feature of mountain fronts.²

ARID REGIONS

Elements of the profile.—The scant rains of the arid regions are sufficient to differentiate sharply the epigene forms there displayed from those deduced above as characteristic of the relief of a rainless

¹ This is due, of course, chiefly to the fact that the amount of disintegration is a function of the extent of surface exposed, and that this is greatest at the top of the scarp where it intersects the reverse slope or a gentler slope in the same direction, but if the scarp be high it may also be due partly to larger contrasts of temperature in higher altitudes.

² This was written before the appearance of Lane's abstract dealing with the same profile in Bull. G. S. A., Vol. 26, No. 1, p. 75.

region. The rain wash co-operates with gravity and transportation is far more efficient. The rock slopes are generally much less than the angle of repose of loose material, the talus is replaced by broad alluvial fans, and for every enclosed basin there is the aggradational flat of the playa. For mountains of approximately homogeneous rock the epigene profile thus comprises three elements: (1) The rock slopes, having an angle of less than 35° ; (2) the alluvial fan slope rarely exceeding 5° ; and, (3) the flat of the playa.

In general these three elements of the profile are easily discriminated one from the other; but in certain cases the angle of the rock slope approaches that of the alluvial fan and the two may be confused. Similarly where the alluvial fan is very flat it may not easily be distinguished in its lower part from the playa. In many desert valleys the playa is located at one end, toward which the drainage flows, so that the fans from the two sides meet in the central part and there is no playa element in the profile for long stretches.

The proportion between the length of the rock slope and that of the fan slope varies greatly. The fans are composed of the detritus washed down from the rock and, as they grow, they rise about the mountain flanks and steadily diminish the extent of the rock slopes. Ultimately the upper edge of the fan reaches the crest of the mountain and there is no farther addition to its surface. A small alluvial embankment on the flank of a mountain ridge is, therefore, significant of an early stage of the degradational process; and a large embankment extending nearly or quite to the crest indicates a late stage. In the deserts of the Great Basin both extremes may be observed. At Genoa, for example, there is a bold, high mountain front of bare rock with a small embankment at its base, and in places none at all.³ At Cima in Southern California the mountain ridge is almost completely buried in its own alluvial waste. From this variable quantitative relation of rock slope and alluvial slope it may be safely inferred that the mountains of the region, considered as features of the relief, are of diverse age. On the basis of this relation it is possible to classify the desert mountains chronologically. Some came into existence so long ago that their rock slopes have been almost entirely buried in their own waste; while others have had their origin so recently that the effect of aggradation about their flanks is relatively slight. Between these extremes a graded series may be recognized significant of a time-sequence. This criterion for the chronological

³ Bull. Seism. Soc. Am., Vol. II, No. 3, Sept., 1912; U. S. G. S. Prof. Paper 73, p. 189, 1911.

classification of the salient features of the relief of the desert may attain a notable degree of exactitude if mountains lithologically similar be compared within the same climatic province.

The degree of acclivity of the epigene slopes of the desert is, on the other hand, no indication of the stage of advancement of the degradational cycle. Under humid conditions hard rocks that are susceptible of chemical decay, and so form soil, tend to acquire more and more gentle slopes as time goes on. A steep slope in such rocks is indicative, in general, of geomorphic youth, whereas a gentle slope is characteristic of old age. In the desert, however, hard rocks present persistently steep slopes throughout the entire period of their degradation. The epigene rock slopes appear to be just as steep in old residual mountains, almost buried in alluvium, as in youthful mountains with but a small embankment of detritus at their base; and it will be shown that they are in reality somewhat steeper.

If the mountain mass be heterogeneous the rock slope may not be uniform, and it may so far depart from the law governing the slopes of homogeneous material that it will assume temporarily the form of a vertical cliff. This is particularly well exemplified where a hard, resistant stratum lies at low angles upon soft beds, as in the case of the Vermilion Cliffs. Here the factors of heterogeneity and structure dominate the degradational process and the climatic control is relatively slight. The result is an escarpment which is not peculiar to the desert, but which may equally well be produced in humid climates, where the same structure and lithologic heterogeneity prevail, as is exemplified in the Niagara escarpment.

But even where the condition of approximate homogeneity obtains it is possible that other agencies than those noted may modify the profile. The wind may be both a transporting and a corradng agent, making for aggradation in one place and degradation in another. While this agency is recognized as of possible importance in regions where powerful winds prevail, particularly where mountains are largely composed of soft, fine-grained, incoherent rocks, it will not here be further considered. The wind, in regions of hard elastic rocks such as are commonly found in the ranges of the Great Basin, is an extremely inefficient agent in the evolution of the profiles of the relief. It is concerned chiefly with local transport of the silts and sands of the playas and with fitful whirling of sand over the fan slopes. The occasional sandstorms doubtless carry notable quantities of fine sand from one part of the desert to another and to regions beyond its

confines. But the wind thus employed plays almost no part in the direct reduction of the rock slopes, in the building up of the fans or in the filling of the playas, the processes which it is the purpose of this paper to discuss.

Degradation.—The encroachment of alluvial embankments upon the mountain slopes from which they are derived is a general phenomenon peculiar to the desert. To arrive at a proper appreciation of the process of encroachment we must first consider the degradation of the rock slope. The waste of mountains in arid regions is effected, as is well known, chiefly by the mechanical disintegration of the surface due to differential dilatation and contraction. The chemical decomposition of the rocks, due to bacterial action, which so largely contributes to the formation of soil in humid regions, is here relatively insignificant. The degradational process is one of transportation of the products of disintegration to lower levels. Corrasion by running water is quite a subordinate part of the process except in those ranges which are so high as to have a relatively abundant precipitation upon their summits. The streams thus fed corrade and deposit in accordance with the general laws so admirably elucidated by Gilbert.⁴ But in most cases the quantity of detritus shed from the sides of the cañons increases faster than the enlargement of their carrying capacity due to the widening of their catchment area, so that early in their career they become habitually incapacitated in their lower stretches, and build up fans or cones of detritus which extend well up into the trunk cañon, forming accentuated features of the general alluvial embankment on the flanks of the mountain. If we confine our attention to the movement of detritus upon the slopes, rather than in the line of these exceptional streams, the rains which supply the transporting agency are characteristically of brief duration, local and violent. Practically all the reduction of the rock slopes and all contribution to the alluvial embankments, whether apexing in the line of perennial streams or not, is effected at these brief and infrequent periods of heavy downpour. When the rock slopes have once been reduced to an angle less than the angle of repose of loose material, the removal of the fragments upon their surface is conditioned by their size and shape. Should they be prevailingly rotund the fragments would move down a gentler slope than if they were irregularly prismatic. To simplify the discussion I shall assume that rock frag-

⁴ Geology of Henry Mountains.

ments in general are irregularly prismatic in shape, which assumption agrees with observation.

For a given size of fragment the ease with which it may be moved diminishes with the decrease of the angle of slope at the place where it rests. Finally a minimum or limiting angle is reached below which the fragment cannot be moved. This limiting angle thus becomes a constant feature of that portion of the slope, say near the top of the slope, throughout all its future degradation under the assumed climatic conditions. For, if the angle of slope become lower, this and other similar sized fragments would encumber it and protect the underlying rock from further disintegration, and degradation would cease. But the fragments shed from a rock slope vary greatly in size, and those which determine the angle of slope are the spauls of maximum size, or perhaps better, the maximum order of size. All loose detritus shed from the rock slope of less order of size is readily carried down the slope in times of cloud-burst. Those of the maximum order represent the limit of size that can be transported. It may be presumed that rocks similar as to lithology and structure shed fragments of about the same maximum order of size, and, therefore, have slopes of about the same angle for similar parts of mountain fronts; whereas dissimilar rocks shed fragments the maximum order of size of which may differ greatly.

But the angle of slope for the upper part of a mountain front in homogeneous rock is not necessarily the angle at the lower part of the same declivity. It is clear from the bare character of the desert fronts that the sheets of water which wash down the detritus in times of cloud-burst are underladen; otherwise there would be a residue of debris left behind and the slope would be undergoing alluviation and not degradation. The fact that the flowing water is underladen and that the volume of water increases in an arithmetical ratio as it descends determines an acceleration of velocity toward the lower part of the rock slope. This in turn determines that spauls of maximum order of size may be moved on a lower angle of slope than at the top of the slope where the velocity is less. A lower angle is, therefore, developed at the lower part of the rock slope. This in turn tends to check the increase of velocity; but, in view of the fact that the slopes are bare and that the water which keeps them bare is underladen, it is evident that the acceleration of the velocity while lessened is not inhibited. Now in any desert range, as the rock slope shortens by the rise of alluvium on its flank, the contrast between the

velocity and volume of water near the top of the rock slope and near the bottom steadily diminishes, so that the angle near the bottom of the shortened slope is greater than at earlier stages of longer slope; while the angle near the top of the slope remains constant. It follows from this that the general angle of the shortened slope, from top to bottom, is higher than for the earlier longer slope.

In this deduction we have the explanation of the observational facts: (1) That the hard-rock slopes of desert ranges which shed large spauls are steep, while those which shed small fragments have a low angle; (2) That ranges composed of hard rock, which are thus naturally steep, maintain their steepness as long as the rock slopes endure. We discover, moreover, that they become gradually steeper with age, the slight upward concavity approximating more and more a straight profile as the rock slope becomes shorter. There is, however, notwithstanding this straightening of the concavity of the profile, a persistent tendency to over-steeping at the very top of the rock slope, where the gravitative work of moving fragments has little aid from flowing water.

Alluviation.—Assuming the correctness of the hypothesis that the angle of the epigene rock slope in the desert is determined by the maximum order of size of the rock fragments shed from its surface by mechanical disintegration, and, therefore, after adjustment does not diminish throughout the entire period of its recession, we may apply it to the development of the mountain profiles. There is abundant evidence that, in the geological epoch of which the present forms a part, but of which the beginning is indefinite, the great alluvial fans which flank most of the mountains of the Great Basin have been steadily growing. For the greater part of this growth the slope of the surface has been approximately constant for every embankment. The increments of growth have, therefore, been of the nature of additions of uniformly thick layers of detritus to the top of the embankment. For each layer thus added to the embankment an equal volume, less the voids, has come from the mountain front. In general, therefore the average vertical cross-section of the embankment may be considered for the purpose of this discussion to have the same area as the average cross-section of rock removed from the mountain front, if we ignore wind action. The growth of the alluvial embankment proceeds, however, not only upward by the accretion of successive layers, but also horizontally by the increasing extent of the layers. Each layer added to it extends farther toward the crest

of the range than the preceeding layer and so diminishes the height and breadth of the rock slope, the recession of which is at all stages limited by the upper edge of the embankment. The rock surface below this upper edge becomes fixed in position by burial.

Truncation.—It follows from this that the buried slope is a shelf or bench cut into the mountain, the inclination of which is somewhere between that of the still exposed rock slope and that of the alluvial embankment. This relation is shown in the diagram, figure 2. The upper limit of the buried bench, the upper edge of the alluvial embankment and the lower limit of the subaerial front are coincident at all stages of the general process. When the edge of the alluvium reaches the crest the subaerial front has disappeared. What is true

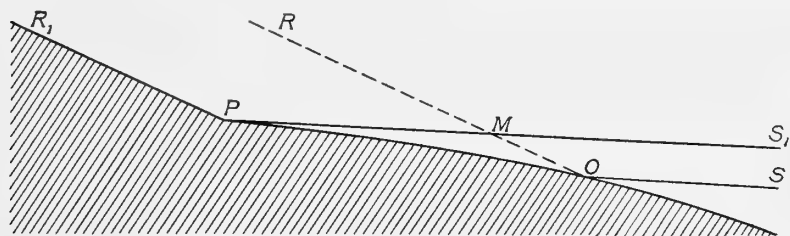


Figure 2.—If the surface of the alluvial embankment OS rises to PS_1 , the rise is coincident with, and due to, the recession of the mountain front from OR to PR_1 . The upper edge of the embankment migrates from O to P , and the rock-cut bench OP is evolved, but is buried as fast as it is cut.

of one side of the mountain ridge is true of the other, so that the rocky crest disappears by the meeting of the feather edges of the alluvial embankments, or rather by their coalescence with the unmoved products of the disintegration of the crest rock. Thus, if the mountain be lithologically and structurally homogeneous, it is reduced by truncation to a low rock ridge with symmetrical slopes wholly buried by alluvium, which on either side is wedge-shaped in cross-section, the edge of the wedge being at the crest and the butt out in the valley. The upper surface of this alluvium is a gentle slope of great stability for the prevailing climatic conditions.

But homogeneity is rarely realized in mountain masses and the heterogeneity varies the rate of the process in different parts and diversifies the ideal symmetry of the result. Owing to differential disintegration and recession, one part of the rock crest may disappear while another portion is salient, and the migration of the lowering rock crests may proceed unevenly. Similarly, resistant portions of

the mass become shoulders and these are usually isolated in the rising flood of alluvium, as it creeps up the slope, and appear as island-like, conical rock hills protuberant above the slope. This diversity in plan and in profile is usually notable in the incomplete stages of the general process. At completion all the rock crest has disappeared, but the line of meeting of the opposing embankments may remain sinuous. Many of the island-like conical hills become eventually buried; but others that rise above the ultimate limit of the alluvial slope remain, of course, protuberant, till as local centers of recession and alluvial distribution they waste slowly away, and become mere patches of the bedrock obscured by the residual unmoved products of disintegration, nearly, but not quite flush with the general slope.

Under exceptional conditions the resultant profile may be asymmetric. For example, if the initial profile of the mountain be steep on one side and so gentle on the other that alluvial debris cannot be transported over it, then the reduction of the mass will proceed on the steep side only. When the rock surface on this side has been wholly buried by alluvium and the process of reduction has come to an end, the profile will be that of the fan slope; but on the other side it will be that of the initial slope, although the surface may be encumbered by the sedentary products of disintegration.

The Resulting Surface.—The result described has been attained in southern California; and various stages of the process may be observed throughout the Great Basin. It is a stage of geomorphic development at which the processes of degradation and aggradation, in so far as they are due to the agency of water, both almost cease. There are no exposed rock slopes to be degraded and the embankments can receive no farther increment. The slopes of the latter are close to the minimum angle for transportation and therefore are not themselves susceptible of vigorous attack. With the disappearance of the rock crest the process of degradation changes from one of relative rapidity to one of extreme slowness. The wind doubtless tends to modify the result, but in the Great Basin this tendency is extremely ineffective; and no important modifications have been observed to affect any stage of the general process or the result, except that locally sand derived from the playas may drift over the alluvial slopes in the form of dunes, which may thus be partially incorporated into the growing embankments.

The symmetry of profile which is attained in the normal process of concurrent degradation and aggradation in the desert is of course a symmetry of angles of slope. It does not extend to the length of

the slope. This quantity is determined by the distance between the ultimate crest of the degraded buried range and the median line of the ultimate aggraded valley on either side. If these distances are unequal, then the playas in the valleys stand at different altitudes, the longer slope reaching out to the lower valley. It follows from this that difference of altitude of the playas on the two sides of a symmetrically sloped range introduces no element of instability into the profile. The playas represent the bottoms of distinct enclosed basins, but when the general condition above outlined has been attained there is no tendency for the lower basin to capture the higher, so long as the climatic conditions remain constant. Such capture may be effected in part by the migration of the crest of an initially asymmetric or heterogeneous range as an incident of the general process, but once the rock crest vanishes the tendency to migration ceases and capture is no longer possible. The surface thus evolved is, in its ideal completion, wholly one of aggradation, a vast alluvial fan surface to which for convenience in discussion I propose to give the name *panfan*.

The Panfan Stage of the Geomorphic Cycle of the Desert.—The panfan may be regarded an end stage in the process of geomorphic development in the same sense that the peneplain is an end stage of the general process of degradation in a humid climate. The peneplain closes the cycle of degradation and is a cut surface; the panfan closes a cycle of degradation and aggradation, is evolved by both cutting and filling, and is a built surface. Like the peneplain, the panfan is rarely observed in its ideal completion. The time required for its completion is so long that diastrophic or climatic changes usually interrupt the process, and even where it escapes those interruptions the final result is subject to destruction by the same changes. We may not expect, therefore, to find the panfan a prevalent feature of the relief of deserts which have been subject to such diastrophic and climatic vicissitudes as have from time to time overtaken the Great Basin or portions of it. Exceptionally, however, it does occur, as in parts of southern California; and in various stages of incompleteness is one of the commonest features of the desert.

The recognition of the panfan as a phenomenon to be classified is, however, not so important as is the perception of the process⁵ whereby

⁵ This process has been fully recognized by Sidney Paige in his paper "Rock-cut Surfaces in the Desert Ranges," *Journal of Geology*, vol. 20, 1912, and he has the honor of first summarily stating it. The conclusions set forth in the present paper may be considered as an amplification of his observations, although they were arrived at independently, and are, therefore, a corroboration and not merely a restatement of his views.

it is evolved, or the conception of it as a *quasi* limiting stage of the degradation cycle of the desert. Appreciation of the process enables us to understand certain features of the desert relief which are otherwise unintelligible; and without the concept of the desert cycle, as here defined, it is impossible to read the geomorphic history of such regions.

From the foregoing discussion it is apparent that bold relief in the desert is subdued partly by degradation and partly by aggradation in reciprocal relation, and that the degradational process produces two rock surfaces, one of which vanishes at the close of the cycle while the other then attains its maximum extent. The former may be referred to as the subaerial front and the latter as the suballuvial bench. Neither of these rock surfaces is in evidence at the panfan stage of the cycle. The subaerial front has been reduced to nothing and the suballuvial bench is, as at all stages, buried. If, however, there be introduced at some part-way stage a diastrophic movement which not only interrupts the normal course of the cycle, but also promotes the destruction of the alluvial embankment, then we may by resurrection have the suballuvial bench revealed as an element in the visible profile. Such stripping of the fans might be effected by faulting or doming which would increase the angle of the surface slope. A general elevation of the region without local faulting or doming might produce the same result, if precipitation upon the summit region were thereby increased to the extent of supplying streams competent to dissect the fans.

Such diastrophic or climatic interruption of the normal course of the desert cycle, resulting in the stripping of the upper parts of the embankments, affords the probable explanation of certain broad rock terraces which are found on the flanks of some of the desert mountains of California, Nevada, Arizona, New Mexico and Mexico.

Such rock terraces have been described by McGee,⁶ who ascribed their origin to sheet flood erosion, and by Paige,⁷ who dissents from McGee's hypothesis of sheet flood erosion and correctly interprets them as resurrected surfaces due to the stripping of the alluvium which once rested upon them.

The Suballuvial Bench.—The general genetic relations of the suballuvial bench having been stated, some details of its configuration and of the law governing its development may briefly be discussed. Neither

⁶ Bull. Geol. Soc. Am., vol. 8, pp. 87-112, 1897.

⁷ *Loc. cit.*

in the foregoing discussion nor in that which follows is any assumption made as to the mode of origin of the initial mountain masses of which the present ranges, of the Great Basin for example, are the degraded remnants. We may begin at any immature stage of the cycle which culminates in the peneplain, and from observed facts deduce conclusions which are independent of the original configuration of the relief and of the genesis of that relief. These conclusions take the form of a prediction of what results will ensue if the existing conditions continue and a statement of what has happened during the persistence of those conditions in the past. For such a starting-point we may take any ordinary basin range with its characteristic steep subaerial front and flanking alluvial embankment. For simplicity I shall assume first that the mountain front considered is the edge of a flat-topped plateau or mesa of homogeneous, strong rock. As the subaerial front recedes, the surface of the embankment rises parallel to itself, but at a diminishing rate owing to (1) the increasing breadth of the alluvial slope and (2) the decreasing height of the prism of material taken from

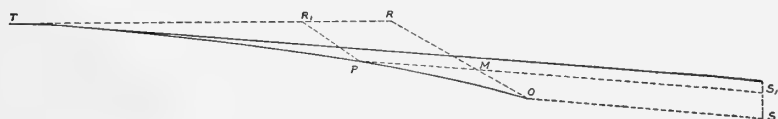


Figure 3.—Recession of front of a mesa from OR to T . The embankment is built up by smaller and smaller increments in equal times owing to the diminishing height of the front and the increasing width of the embankment. But the recession of the front is at a uniform rate; therefore the rock-cut bench OPT is a hyperbolic curve convex upward.

the front and added to the embankment. The rate of recession of the subaerial front is, however, uniform and it results from this that the suballuvial bench is a curved surface convex upward, defined by the locus of the intersection of the fan surface and the surface of the subaerial front. This relation may be expressed mathematically by reference to the diagram, figure 3. The profile with which we start is $TROS$, of which TR is the level plateau summit, RO is the subaerial front and OS is the surface of the alluvial fan. R_1P is a second stage of the subaerial front and PS_1 is the fan surface at the same stage. A is the angle which the subaerial front makes with the horizon and B is the angle of the alluvial fan. OP is the suballuvial bench cut in the transition from the first stage to the second. Let x and y be the oblique coordinates of the curve OPT , the origin of

which is O . For any point P on the curve, the areas ORR_1P and OSS_1P are equal. From this it follows, by a mathematical treatment which Professor T. M. Putnam has kindly carried out for me, that the equation of the curve OPT is

$$x(OR - y) - \frac{1}{2}x^2 \frac{\sin B}{\sin A} = OSy + \frac{1}{2}y^2 \frac{\cos A}{\cos B}$$

The curve OPT , for the assumed condition of a flat-topped mesa, is a hyperbola to which the limiting surface of the fan is tangent at the point T , where the hyperbola intersects the mesa surface.

It is apparent from this, that if the mesa be very broad relatively to its height, the suballuvial benches cut on both sides of an elongated mountain block might intersect the surface of the mesa short of the median line, so that on the completion of the process of degradation, the central part of the resulting stable profile would be that of the original mesa. If the mountain block be relatively narrow, and this appears to be the common case, then the suballuvial bench will not intersect the mesa surface, but will meet the corresponding bench approaching from the other side at some point below the level of the summit.

We may now vary our assumption as to the initial form of the mountain. If instead of being a mesa its cross-sectional area from the center to the edge O be less than that shown in the diagram, then the fan surface will rise more slowly and the bench will be flatter without changing the character of its curvature. If, as is usually the case, the mountain mass be higher at its center than on its margin, so that the cross-sectional area be greater than that of the diagram, then the area ORR_1P of one stage of the process may become sufficiently greater than the similar area of the next preceding stage to cause each successive layer added to the surface of the fan to be thicker than the preceding layer, and the curvature of the bench will be concave upward. It thus appears that for the same width of valley some suballuvial benches may be convex and others concave upward; and that the condition which determines the convex curve may change to the one which determines the concave curve, so that the resulting bench may be concavo-convex. In order that the bench should be a straight slope, the fan would have to rise by equal increments in equal times throughout its entire growth, and this is a rare and accidental case.

It is further apparent that the character of the suballuvial bench is a function of the width of the valley, OS , in which the detritus

accumulates. For if OS be large, the rise of the fan surface will be slow and the curvature of the bench will be flat; and if small, the growth of the fan will be rapid and the curvature steeper. But whether OS be large or small, it is the acceleration of the rate of rise of the fan surface which determines whether the curvature shall be convex or concave upward. If the acceleration be negative, it is convex; if positive, concave. And this acceleration is directly due, as has been stated, to the ratios between the areas ORR_1P and OSS_1P in two successive periods of equal time.

It is also evident that if the valley at one end of a uniform mountain ridge be wide and at the other end narrow, the bench will vary from flat to steep, the width of the bench remaining constant. If, on the other hand, we have a mountain ridge low at one end and high at the other, flanked by a uniformly wide valley, there will be developed a flat bench at the low end of the range and a steep bench at the high end; and similarly for other relations of mountain and valley.

In the ordinary case, where the surface of the alluvial embankment rises by diminishing increments and the surface of the suballuvial bench is consequently convex upward, an interesting condition develops in the late stages of the general process. In cross-section the direction of the embankment slope is asymptotic to the hyperbolic profile of the bench. In the late stages of the recession of the subaerial front, when its height is relatively small, and the embankment is relatively broad, the latter rises very slowly by increments that are nearly equal; and the hyperbola approaches very closely to a straight line and to tangency with the surface profile of the embankment. The profiles of both the bench and the embankment, though mathematically distinct, are then practically coincident. Under these conditions the horizontal extension of the embankment does not keep pace with the recession of the subaerial front. Between the upper edge of the embankment and the base of the front there is evolved a graded rock slope. The suballuvial bench becomes at this stage a subaerial bench, across which the detritus from the vanishing front is swept in times of cloud-burst, to be spread over the surface of the embankment below. This emergence of the bench and its persistence as a subaerial feature appears to be most characteristic of granite ranges which disintegrate into fragments composed chiefly of the individual mineral constituents, and therefore very uniform in size. The phenomena are exemplified in the group of mountains in southern

California west of the Colorado River near the Needles, as illustrated in the photographs,⁸ plates 1 and 2. Here broad alluvial embankments, from six to ten miles across, rise by a gentle slope to the summits of the ranges, where there are residual rock crests, or "nubbins," and stretches where the crest has entirely vanished as a protuberance above the general slope. Within a mile or more of the summit one passes, without appreciable change of slope, from the alluvial detritus of the embankment on to a bare rock surface extending to the nubbins of the crest. The upper limit of the alluvium is a feather-edge.

It thus appears that, in addition to the rock terraces of desert ranges due, as explained by Paige,⁹ to the stripping of suballuvial benches of the alluvium which once mantled them, we have to reckon with similar features, which may be evolved subaerially, and yet not by any process of sheet flood erosion, but by the normal process of recession of mountain fronts.

The Alluvial Embankment.—The mode of growth of the alluvial embankment determines certain features of structure which may be of service as criteria for distinguishing it from other types of deposits in the formations of past ages, when it appears as an element in problems of stratigraphy. The discrimination desired may usually be readily made in the coarser portions of the embankment by a mere inspection of the character of the constituent fragments. The characteristics of fanglomerate have been briefly described in a former paper¹⁰ and in good exposures there is little likelihood of it being confounded with either a marine or a fluvial conglomerate. The finer deposits on the outer edge of the embankment and those of the playa are, however, not so easily distinguished from delta deposits either above or below sea-level, or from lacustrine deposits. It is therefore desirable to point out in what respects the configuration and internal structure of an embankment of the desert differs from other sedimentary formations which are commonly met with in studies of the earth's crust.

Considered as a whole, the alluvial embankment of the desert is elongated in a direction transverse to the movement of the material which comes to it. It results from this that the grading of size of

⁸ These photographs and the descriptions of the conditions which they illustrate were kindly supplied by Messrs. W. L. Moody and A. W. Lawson, of the geological staff of the Southern Pacific Company.

⁹ *Op. cit.*

¹⁰ Univ. Calif. Publ., Bull. Dept. Geol., vol. 7, no. 15, 1913.

its constituent material is transverse to its general elongation, the tendency being for the coarser material to remain on one side and the fine to be carried to the other, at any and every stage of its growth. Owing to the fact that the embankment transgresses the wasting mountain mass, the fan growing broader as it rises, the fine material of a late stage of its growth may be, and usually is, directly above the coarse material of an earlier stage, with a gradation between. The reverse condition of coarse above fine never occurs except where the embankment has been dislocated by a large fault, the scarp of which would supply a local source of coarse material.

But from a formational or stratigraphic point of view the embankment which flanks a wasting desert mountain ridge cannot be considered alone. Nearly all such embankments have a twin or symmetrical relation to another embankment on the other side of the valley, and the fill of the valley must be considered as a whole. From this point of view the formation is a twinned embankment with similar structure on both sides of its axis of symmetry. In the later stages of its growth the central part, the playa, is composed of fine silts and sands flanked on either side by arkose, the latter in turn grading towards the sides into coarse fanglomerate. But as to the distribution of the different grades of material in the early stages of the growth of the twinned embankment in particular cases we can speak only in a speculative way, because we rarely have information as to the configuration of the country when it first came under the sway of aridity. We may, however, discuss to advantage an assumed case for the purpose of clarifying our ideas as to the essential features of the internal structure of the embankment, recognizing that the results deduced will vary greatly with other assumptions as to the initial condition.

We may suppose: (1) That a deep V-shaped valley evolved by erosion under humid conditions is suddenly brought under conditions of aridity; (2) that by crustal warping or by alluviation the valley becomes an enclosed basin; and that (3) the rocks are homogeneous. In the course of time, by the recession of the valley sides from ON and ON' to FM and $F'M'$ in figure 4, the suballuvial benches OF and OF' will be cut and the surface of the twinned embankment will rise to FPF' . At this stage the profile of the valley and the adjacent mountains will be that of the ordinary desert valley in the Great Basin. I do not suggest that the broad alluviated valleys of the Great Basin thus originated as valleys of erosion in a humid climate; but

that they may have done so is clearly possible. This possibility is not here introduced in a discussion of the origin of these valleys, but to bring out the essential structure of the embankments which fill them, whatever may have been their initial profile and mode of formation. Considering now the surface profile of the valley $MFPP' M'$ as typical of the present valley of the Great Basin, the materials which form the surface of the embankment may be for convenience classified into three grades, coarse, medium and fine. The point a may be taken as the outer limit of the coarse material and b the outer limit of the medium, and the fine would extend to the center of the valley. Similarly at the successively preceding stages P_1, P_2, P_3, P_4 , the points a_1, a_2, a_3, a_4 , would represent the outer limits of the coarse material at the respective stages. At stages P_5 and P_6 , however, the coarse material would reach the center of the valley and would, therefore, not be sorted from the medium and fine detritus. Also at the

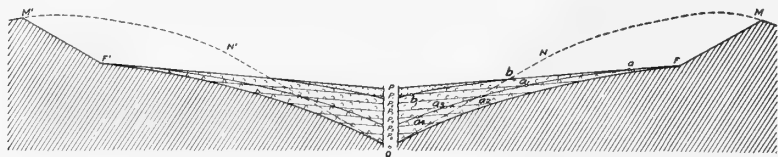


Figure 4.—If the typical desert valley $MFPP' M'$ were evolved from the initial steep-sided valley NON' , there would be developed the twinned embankment FOF' resting on the cut benches FO and $F'O$ and having two intersecting systems of stratiform structure.

stage P_1 , b would be the outer limit of the medium-sized material and the fine would go on to the center of the valley; but at stages P_2, P_3, P_4, P_5, P_6 , the medium-sized material would extend to the middle of the valley and would therefore not be sorted from the fine. The same would be true of the twin embankment on the other side of the valley. Considering now the embankment in ideal cross-section, it follows from what has been said that the coarse detritus is confined to the bottom of the embankment and that its upper limit is the curve drawn through the points a_1, a_2, a_3, a_4 , but that in the central region the coarse is mixed with medium and fine material. Similarly the coarse material is throughout the embankment, from the center of the valley to a , overlaid by medium-sized material the upper limit of which is the curve drawn through b, b_1 ; and above this in the central or playa region is the fine detritus. Of course under actual conditions the demarcations indicated by the points a, a_1, b, b_1 , etc., are gradational, and the locus of the mean position of these points in plan is

an irregularly sinuous or serrate line. Nevertheless the general fact remains that under uniform unchanging conditions we have built up a sedimentary formation, which, by its tripartite stratiform subdivision into coarse, medium and fine material would, and usually does, suggest to the student of stratigraphy rather abrupt changes of general conditions, whereas the only change that has transpired is the gradual recession of the subaerial front, the source of supply of the detritus. From a petrographic point of view these three divisions of the embankment may be referred to in ascending order as fanglomerate, arkose and silt. It is noteworthy that all three increase regularly in thickness away from the source of the material. All three present two kinds of stratification. One of these is a formational stratification determined by the upper and lower limits of the fanglomerate, arkose and silt respectively; the other is the stratification of actual deposition, which is parallel to slope of the surface of the embankment, and is *flatter than the formational stratification*, being thus in contrast to ordinary false bedding, which is steeper than the formational stratification. It is also noteworthy that a central or playa deposit of silts well segregated from arkose can be developed, under the assumed conditions, only at a comparatively late stage of the upbuilding of the embankment. In earlier stages the silt of the central region is mixed with arkose and at still earlier stages with both arkose and fanglomerate.

If our initial valley be wide-bottomed instead of V-shaped there may be ample space for sorting, so that coarse or even medium detritus may not reach the middle of the valley at any stage of the upbuilding of the twinned embankment and lacustral deposition is possible. A similar situation may arise if the valley be a *graben*. Hence the central region of the twinned embankment may vary in the character of its materials and, therefore, in structure according to the initial profile of the valley at the inception of fan building. But for the portion of the embankment that rests upon the suballuvial bench on both sides of the valley the distribution of material and the resulting structure are in all cases in a general way the same.

The transverse profile of the embankments actually observable in the desert is as even and uniform as is indicated in the discussion of the ideal case, except that a slight upward concavity may in some instances be detected. In the longitudinal profile, or that parallel to the range, there is, however, a systematic irregularity, due to what may be described as a transverse fluting of the embankment.

The contour of the subaerial front for the greater part of the time of its recession is not in reality a straight, or even a gently sinuous, line, but is actually indentate. At the indentations are cañons or gullies and from these emerge the greater part of the detritus which forms the embankment and which is distributed radially from an apex in, or at the mouth of, every cañon or gully. It results from these conditions: (1) that the longitudinal profile and contour of the general embankment are sinuous; (2) that the sinuosity is most acute near the mountain and flattens out toward the valley; (3) that the mean limit of the coarse detritus is in plan a sharply sinuous or serrate line and the mean limit of the medium detritus a smoothly sinuous line; and (4) that in the depressions of the longitudinal profile the angle of slope of the embankment is less than in the median lines of the individual fans, and the amount of water available for transportation is less. Since the conditions referred to persist throughout the greater part of the time of the accumulations of the embankment, the internal structure of the latter is regularly more complex than might be inferred from the discussion of the ideal case. This complexity will manifest itself stratigraphically chiefly in the alternate thickening and thinning of the fanglomerate and the arkose in the elongation of these formations parallel to the range, and in an appreciable longitudinal component of dip of the actual depositional stratification in opposite directions on the two sides of the axes of the individual fans. In the later stages of the general process, when the subaerial front is relatively small, this complexity will become less marked; but if the front be reduced to nothing in one part of a range while in neighboring parts it is still a prominent feature, the variation in thickness and in dip of the deposits of the embankment will be again accentuated.

The Subaerial Front.—In the discussion of the ideal case the subaerial front is represented by implication as a mountain slope having a straight contour. This is a conceivable case on the assumption of perfect homogeneity of material and structure; but as a matter of fact none of the mountains of the desert are perfectly homogeneous, and all their subaerial fronts have a more or less indentate contour. The indentation may be slight in the early stages of front recession, is most pronounced in the middle stages and becomes less intricate in the later stages. By supplying a larger surface to atmospheric attack the development of gullies and cañons accelerates the general process of recession, and in so far as the acceleration is local, it

affects the configuration of the resulting suballuvial bench, in two ways: (1) It favors the isolation of salients of the front as island-like rocky cones, which may be submerged by the rising of the alluvium, or project above its ultimate surface and be reduced individually as already described. (2) More regularly disposed inequalities of the surface of the suballuvial bench may, however, result from the acute indentation of the contour of the subaerial front. If we consider the embankment as in large measure composed of an aggregate of fans apexing in the re-entrants of the front, then it is apparent that the cutting of the suballuvial bench proceeds in the direction of the median line of every fan at a higher level than it does along the interfan lines on either side. The result of this is that in longitudinal section the bench will be broadly undulating, just as the profile of the surface of the embankment is. Moreover, since the excess of elevation of the fan areas over the interfan areas means that for a considerable period the surface of the embankment rises more rapidly in the former than in the latter, the slope of the bench in the median line of the fans will be somewhat steeper than in the line of the interfan depressions.

The conditions which determine the indentate character of the receding front and so cause these irregularities in the suballuvial bench may be in some cases mere accidents of initial configuration, but they inhere chiefly in the heterogeneity of the mountain mass. Some of the rocks of which it is composed are more susceptible of degradation than others and so recede at a more rapid rate. But rocks which are least susceptible of degradation in a humid climate may be most easily degraded in the desert. The most easily eroded rocks under humidity are those which pass most rapidly into soil by chemical decay; whereas in the desert the most rapidly receding fronts are composed of rocks most prone to mechanical disintegration. Thus, of two common types, quartzite and greenstone, the latter in a humid climate may be easily decomposed to a pulverulent soil while the quartzite, being little affected by bacterial action, is less rapidly eroded, and forms eventually the residual ridges. In the desert, on the contrary, the greenstone, being tougher, is not so readily disintegrated as the highly elastic quartzite and the latter, therefore, recedes more rapidly. It thus happens that the re-entrants of a subaerial front of a desert range may be developed along belts of the harder rock and the salients may be composed of softer, less elastic rock.

The Ultimate Stage.—The peneplain is, as the term implies, a penultimate rather than an ultimate stage of geomorphic development under persistence of uniform conditions. The final stage is a plain; but the term peneplain is conveniently used to cover both the penultimate and the ultimate stages, since the latter is only rarely observed, or inferred. Similarly the panfan is a penultimate stage in the reduction of the relief of the desert under conditions of crustal stability. There remains, therefore, the question of the ultimate stage and of the transition from the penultimate to the ultimate stage.

A desert reduced to the panfan stage may still be subject to cloud-bursts, unless the smoothing out of the relief react upon the climate and minimize still farther the precipitation. If such a reaction be assumed, then we must recognize in the consequent increase of aridity a tendency which would make for preservation of the panfan stage. If, however, the aridity be not intensified by the reduction of the relief, then it seems probable that the forces which had hitherto been engaged in building the embankment would become effective for its modification. This modification would be manifest as a transfer of finer material from higher to lower levels, which would build up the playa at the expense of the fine and medium-sized material on the middle slopes. The process would of course be in operation long before the attainment of the panfan stage, particularly when cloud-bursts were local to the fan slope and did not affect the subaerial front. But as long as the latter continued to be a source of abundant detritus the modifying tendency would be counteracted and masked by the normal upbuilding process, except that it might appreciably contribute to a slight upward concavity in the fan profile. With the disappearance of the subaerial front the cloud-bursts falling upon the fan surface would be more effective for the transfer of material from higher to lower levels, the running water being no longer charged with a load from above the fan. This transfer would first accentuate the upward concavity of the fan profile by (1) leaving the upper part of the embankment relatively little affected, owing to the large size of the fragments and the greater porosity in that region; (2) degrading the middle slopes where the material is finer and less porous; and (3) adding the transported material to the toe of the embankment and to the playa. What the limits of this modifying process may be, without the stimulus of crustal deformation, it is difficult to predict. With increasing upward concavity the position of the coarse detritus on the upper margin of the embankment would become less stable and,

given sufficient time, might be withdrawn from the crest and expose the suballuvial bench. This would be the more probable if the fragments of rock constituting the upper edge of the fan were subject to still farther reduction of size by mechanical disintegration. In some kinds of rock of a coarsely crystalline texture, such as granite, and particularly porphyritic granite, this reduction of the size of fragments appears to occur regularly, while in other more homogeneous rocks the fragments appear to be able to withstand differential dilatation and contraction without rupture after they have reached a certain size. For granitic rocks, therefore, we might expect a stripping of the suballuvial bench at the crest. The latter would then become subject to renewed disintegration, and some of the new detritus would be transported down the slope; but eventually the angle would become so low that the detritus would remain as a permanent mantle protecting the underlying rock from further waste. The limit of degradation of the middle slopes of the fan would be reached when the line of demarkation between the freely permeable and the relatively impervious detritus had migrated down the slope nearly to the level of the playa.

Transmitted August 14, 1915.

EXPLANATION OF PLATE 1

Looking North along Manchester Divide, near Needles, California. Showing alluvial embankment extending up to base of "nubbins" or residual crest of mountain range. An approximation of the panfan stage of the desert cycle. The subaerial front is small and the suballuvial bench and alluvial embankment both large, the latter being from 8 to 10 miles in width.

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Photo. W. L. Moody

EXPLANATION OF PLATE 2

Looking south-east toward divide south of Sunrise Peak, 20 miles Southwest of Needles. The upper feather-edge of the alluvial embankment fails to reach the base of the subaerial front, and a bare even rock platform one to two miles wide, having the same angle of declivity as the embankment, extends out from the "nubbins" at the summit. Beyond this the slope has a width of from 6 to 8 miles to the base of the alluvial embankment.



Photo. W. L. Moody

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Vol. 9, No. 4, pp. 49-58, 12 text figures

Issued November 22, 1915

**NEW HORSES FROM THE MIOCENE AND
PLIOCENE OF CALIFORNIA**

BY

JOHN C. MERRIAM

UNIVERSITY OF CALIFORNIA PRESS
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INTRODUCTION

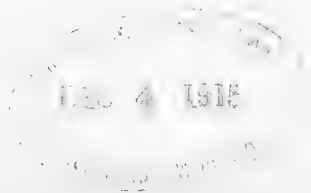
In a study of the Tertiary mammalian faunas of California several new species of protohippine horses have appeared. The designation of these forms is desirable at this time in order that reference to the species may be possible in publications which will appear in advance of the papers including detailed descriptions of the new forms.

MERYCHIPPUS SUMANI, n. sp.

Merychippus, near *calamarius*. Merriam, J. C., Univ. Calif. Publ. Bull. Dept. Geol., vol. 6, p. 168, pl. 29, figs. 1a to 1c, 1911.

Type specimen, no. 21422. Barstow Upper Miocene, Mohave Desert, California.

Upper cheek-teeth much smaller than in typical *Merychippus calamarius* or in *M. intermontanus*. Crowns of cheek-teeth considerably elongated, markedly curved, and well cemented; height of the crowns often equal approximately to twice their width. Protocone round, tending toward circular form in cross-section, and discrete up to a stage of very advanced wear. Enamel bordering the fossettes commonly more complicated than in any of the larger *Merychippus* forms of the Barstow Miocene.



This species includes the smallest members of the *Merychippus* series in the Barstow Miocene. It is closely related to *Merychippus calamarius*, and may possibly represent merely a variety of that group. In the characters of the cheek-teeth this species approaches *Hipparion*, from which it is distinguished by the more strongly curved crowns of the upper teeth, and by the greater simplicity of the enamel borders of the cement lakes. The cement covering of the cheek-teeth is commonly thinner than in *Hipparion*, and there is no evidence of functional cement on the milk molars.

Named in honor of John R. Suman who furnished the first specimen of this species used in study of the Mohave Tertiary faunas.

MEASUREMENTS OF TYPE SPECIMEN, No. 21422

Length, anterior side M ¹ to posterior side M ³	57 mm.
P ¹ , anteroposterior diameter	22.
P ¹ , transverse diameter	20.8
P ¹ , height of crown	31.3
M ¹ , anteroposterior diameter	19.
M ¹ , transverse diameter	19.4
M ¹ , height of crown	28.5
M ² , anteroposterior diameter	20.8
M ² , transverse diameter	18.1
M ² , height of crown	32.8
M ³ , anteroposterior diameter	19.7
M ³ , transverse diameter	15.5
M ³ , height of crown	32.6

MERYCHIPPUS INTERMONTANUS, n. sp.

Type specimen, no. 21400. An upper cheek-tooth dentition from locality 1401 in the Barstow Miocene of the Mohave Desert, California.

Cheek-teeth large; crowns long, strongly curved, heavily cemented. Protocone of upper cheek-teeth uniting early with protoconule. Enamel walls bordering the fossettes comparatively simple.

This form includes the largest members of the *Merychippus* type in the Barstow Upper Miocene of the Mohave Desert. It is distinguished from the typical *Merychippus calamarius* by its larger size, longer crowns, heavier cementation, and more pronounced tendency to union of the protocone and protoconule even in young individuals. The species more closely approaches the *Protohippus* type than does typical *M. calamarius*, and might by some authors be included within the limits of that genus. It is here referred to *Merychippus* rather than to *Protohippus*, as the milk dentition of a number of specimens presumably representing this type seems to show less cement on the crowns of the cheek-teeth than in typical *Protohippus*.

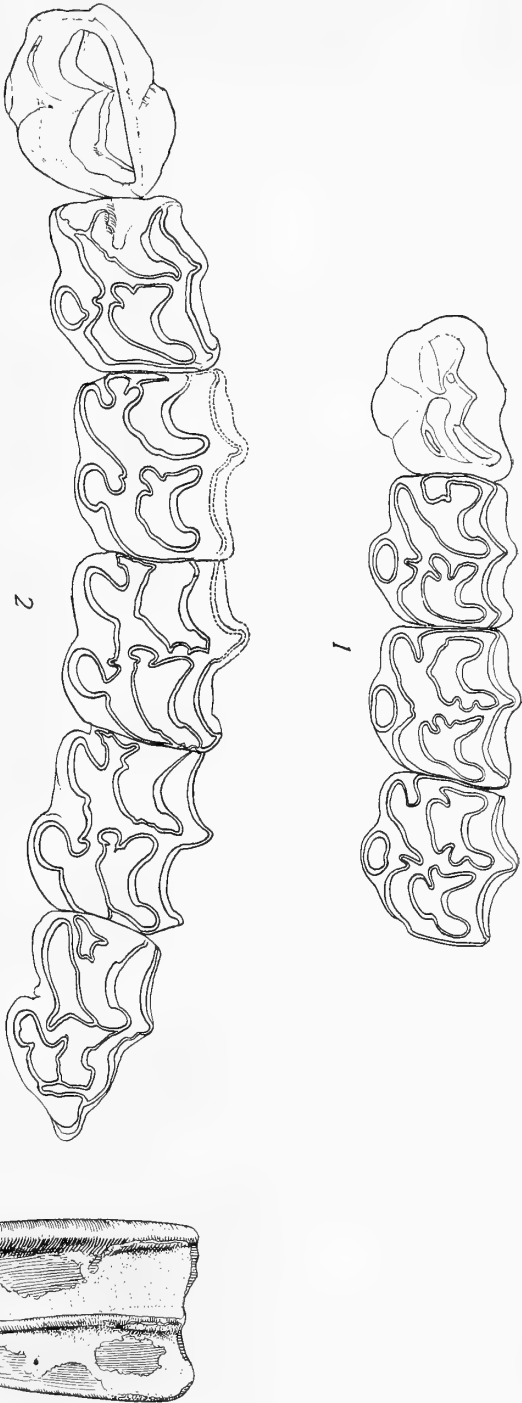


Fig. 1. *Merchippus sumani*, n. sp. Type specimen, no. 21422, superior cheek-teeth, occlusal view, natural size. From the Barstow Upper Miocene, Mohave Desert, California.

Figs. 2 and 3. *Merchippus intermontanus*, n. sp. Type specimen, no. 21400, natural size. From the Barstow Upper Miocene, Mohave Desert, California. Fig. 2, superior cheek-tooth series, occlusal view; fig. 3, M^2 , outer view.

MEASUREMENTS OF TYPE SPECIMEN, No. 21400

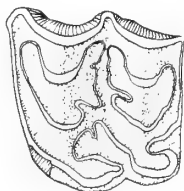
Length, anterior side P ² to posterior side M ³	146 mm.
Length, anterior side P ² to posterior side P ⁴	78.8
Length, anterior side M ¹ to posterior side M ³	67.
P ² , anteroposterior diameter	29.8
P ² , transverse diameter	18.5
P ³ , anteroposterior diameter	24.5
P ³ , transverse diameter	22.7
P ³ , height of somewhat worn crown	44.
P ⁴ , anteroposterior diameter	24.9
P ⁴ , transverse diameter	21.
M ¹ , anteroposterior diameter	24.
M ² , anteroposterior diameter	24.
M ² , transverse diameter	21.7
M ² , height of crown	43.
M ³ , anteroposterior diameter	a 22.
M ³ , transverse diameter	a 18.

a, approximate.

PROTOHIPPIUS TEHONENSIS, n. sp.

Type specimen an upper molar, no. 21779, from the Tejon Hills, southern end of San Joaquin Valley, California.

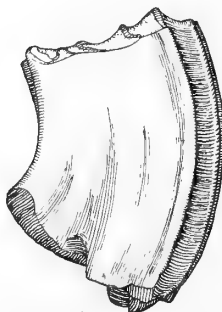
Upper molar crown strongly curved and well cemented; outer styles of moderate strength; protocone considerably flattened transversely and connected with the protoconule by a wide isthmus; fossettes wide transversely and showing plication of enamel only on the adjacent borders.



4a

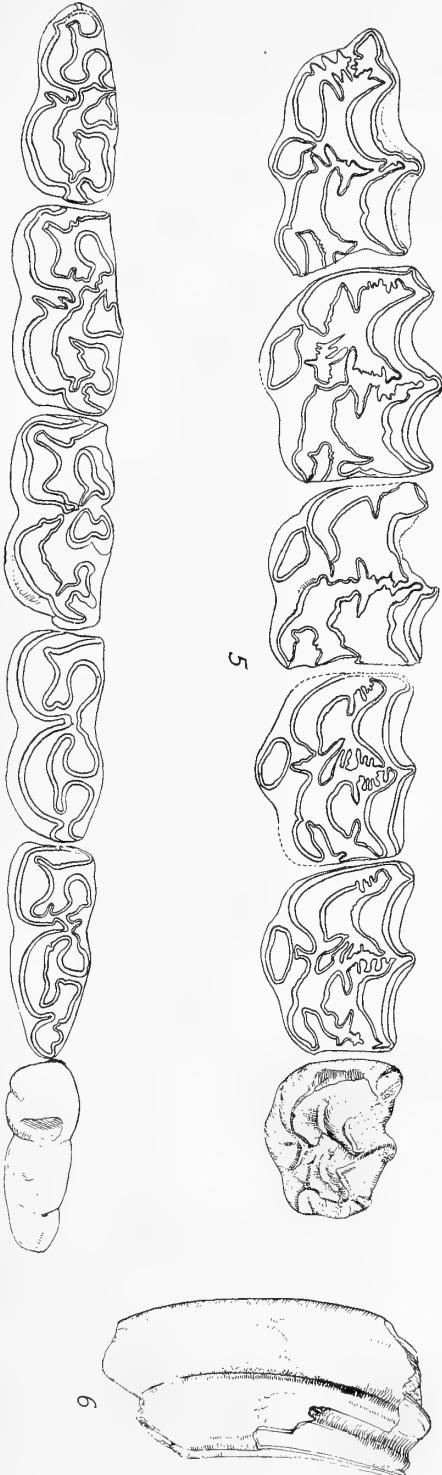


4b



4c

Figs. 4a to 4c. *Protohippus tehonensis*, n. sp. M¹?, type specimen, no. 21779, from the Tejon Hills, southern end of the San Joaquin Valley, California. Fig. 4a, occlusal view; fig. 4b, outer view; fig. 4c, posterior view.



Figs. 5 to 7. *Hippurion mohavense caliodonte*, n. var. Cheek-tooth series, no. 21311, natural size. From the Ricardo Pliocene, near Ricardo Postoffice, Mohave Desert, California. Fig. 5, superior cheek-tooth, occlusal view; fig. 6, M³, outer view; fig. 7, inferior cheek-teeth, occlusal view.

The West-American forms nearest *P. tehonensis* are a rare *Protohippus* or *Pliohippus* represented by no. 21423 from the Barstow Upper Miocene, and a form referred to *Pliohippus* occurring in the lower portion of the Jacalitos Pliocene of the North Coalinga region. The Barstow species is near *P. tehonensis* in form and dimensions, but differs slightly in form of the protocone, strength of the enamel, and possibly in degree of cementation of the crowns. It seems to the writer doubtful whether the Barstow and Tejon Hills forms are specifically identical. The North Coalinga species described by Arnold and Anderson¹ from the Jacalitos formation, and determined as *Pliohippus*, approaches *P. tehonensis* very closely and may be specifically identical. As yet we have only three teeth from the Jacalitos and all represent M³, so that a fully satisfactory comparison cannot be made.

Pliohippus tantalus of the Ricardo Pliocene is larger and heavier than the Tejon Hills species, its fossettes are larger and differently formed. A *Pliohippus* species from Ricardo near *P. mirabilis* resembles the Tejon Hills species in dimensions, but seems to differ in details of form of fossettes and is presumably not of the same species.

MEASUREMENTS OF TYPE SPECIMEN, No. 21779

?M ¹ , anteroposterior diameter	22.5 mm.
?M ¹ , transverse diameter	23.7
?M ¹ , anteroposterior diameter of protocone	a 8.4
a, approximate.	

HIPPARION MOHAVENSE CALLODONTE, n. var.

Type specimen, no. 21311, a finely preserved dentition including the upper and lower cheek-teeth with several of the incisors. Collected in the Ricardo Pliocene near Ricardo Postoffice, on the western border of the Mohave Desert, by Emerson M. Butterworth.

In this form the dentition differs noticeably from that of the typical *Hipparion mohavense* of the Ricardo Pliocene. The protocone is more strongly flattened transversely, while the enamel pattern of the teeth in general shows fewer deep, smoothly-rounded folds. The plications of the enamel in this form tend to be more distinctly angular, and there are more numerous minute folds. The dimensions differ somewhat from those of the typical *H. mohavense*. The differences in dimensions and in pattern of the cheek-teeth separating this variety from typical *H. mohavense* may be due in some part to variation in stage of wear, but the characters seem sufficiently marked to

¹ Arnold, R., and Anderson, R., Bull. U. S. Geol. Survey, no. 398, p. 98, 1910.

require at least tentative recognition in the classification. It is possible that fuller collections may ultimately show an intergradation between this form and *H. mohavense*.

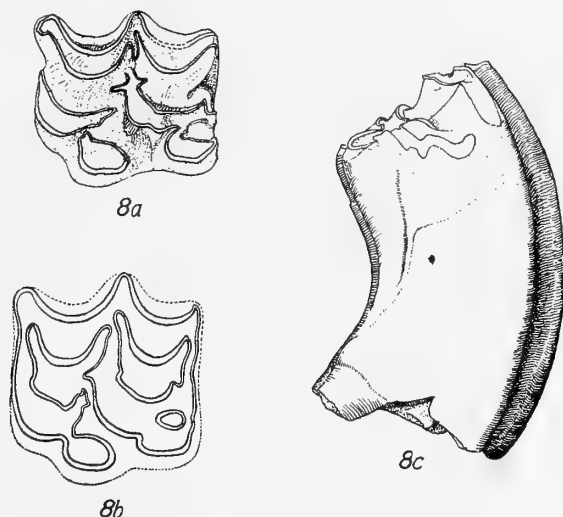
MEASUREMENTS OF NO. 21311

P ² , anteroposterior diameter 29.9 mm.	P ₂ , anteroposterior diameter 28.4 mm.
P ² , transverse diameter 20.2	P ₂ , greatest transverse diameter 12.
P ³ , anteroposterior diameter 27.4	P ₃ , anteroposterior diameter 27.
P ³ , transverse diameter 23.2	P ₃ , greatest transverse diameter 13.7
P ⁴ , anteroposterior diameter 24.8	P ₄ , anteroposterior diameter 27.4
P ⁴ , transverse diameter 21.5	P ₄ , greatest transverse diameter 13.
P ⁴ , height of mesostyle 45.5	P ₄ , height of protoconid 51.
M ¹ , anteroposterior diameter 24.5	M ₁ , anteroposterior diameter.... 25.8
M ¹ , transverse diameter 22.6	M ₁ , greatest transverse diameter 11.4
M ² , anteroposterior diameter 24.	M ₂ , anteroposterior diameter.... 27.3
M ² , transverse diameter 20.4	M ₂ , greatest transverse diameter 10.8
M ² , height of mesostyle 41.	M ₂ , height of protoconid 44.4
M ³ , anteroposterior diameter 21.	M ₃ , anteroposterior diameter.... 25.
M ³ , transverse diameter 18.	M ₃ , greatest transverse diameter 10.4

PLIOHIPPIUS FAIRBANKSI, n. sp.

Type specimen, a large unworn upper cheek-tooth P⁴?, no. 19789, from the Ricardo Pliocene, near Ricardo Postoffice, California.

The type specimen of *P. fairbanksi* represents a protohippine form differing considerably from *Pliohippus tantalus* of the Ricardo Pliocene. The crown is a little more strongly curved and the styles are heavier. The fossettes are nar-



Figs. 8a to 8c. *Pliohippus fairbanksi*, n. sp. P⁴?, type specimen, no. 19789, natural size. From the Ricardo Pliocene near Ricardo Postoffice, Mohave Desert, California. Fig. 8a, occlusal view; fig. 8b, section at base of upper third of crown; fig. 8c, posterior view.

rower and have a distinctly different form. The protocone is small and round. In this particular specimen the protoloph and metaloph remain separate almost to the base of the tooth.

The nearest approach to the form seen in specimen no. 19789 is that in a tooth type (no. 21341) from the Etchegoin Pliocene of the North Coalinga region of California, on the western border of the San Joaquin Valley. The Etchegoin form shows rather narrow fossettes, a very small, round protocone, and a weak connection of protoloph and metaloph. The cheek-teeth of the Etchegoin species are considerably narrower and less curved than the Ricardo form, and appear to be specifically different.

This species is named in honor of Dr. H. W. Fairbanks, who was one of the earliest investigators to study the Ricardo Pliocene beds.

MEASUREMENTS OF TYPE SPECIMEN, No. 19789

P ⁴ , height of crown on outer side	55 mm.
P ⁴ , anteroposterior diameter	25
P ⁴ , transverse diameter	26.4

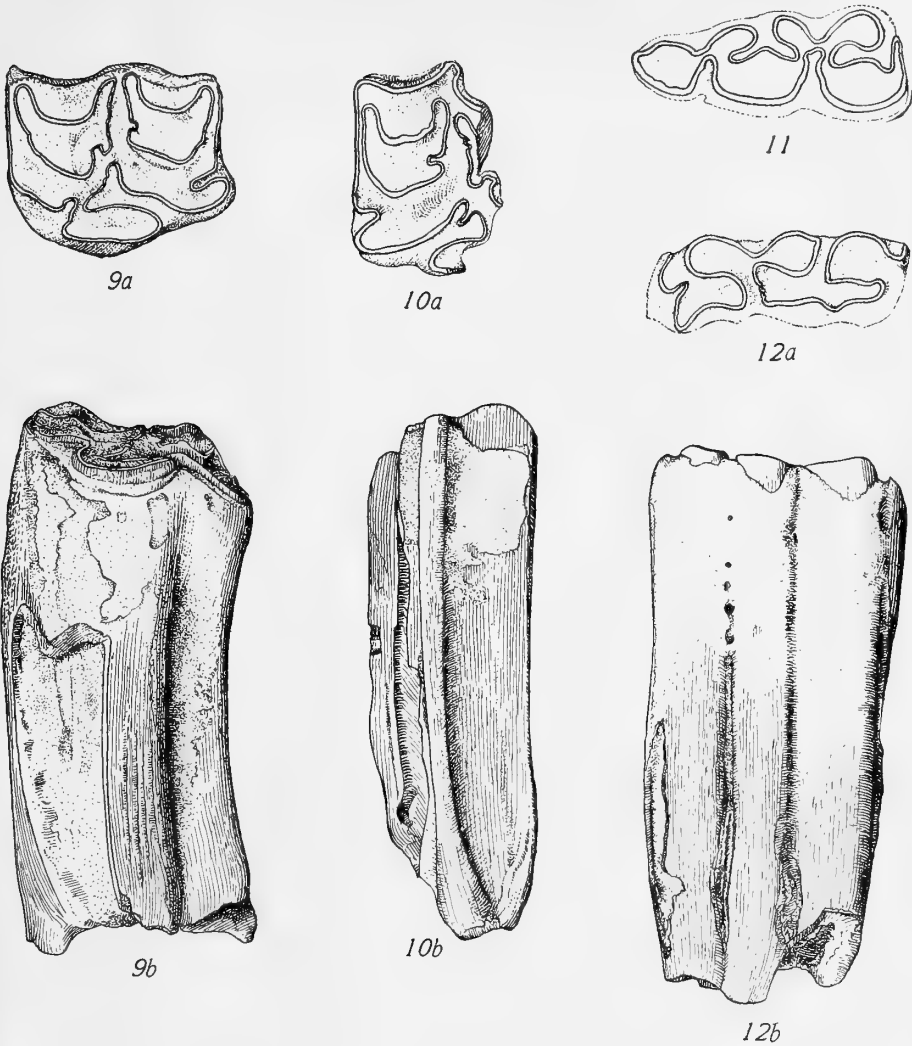
EQUUS or PLIOHIPPIUS, probably new

Equus or *Pliohippus*, sp. Merriam. Amer. Phil. Soc. Trans., n.s., vol. 22, pt. 3, p. 223, 1915.

Upper and lower cheek-teeth, from beds in the upper portion of the Etchegoin formation north of Coalinga.

Cheek-teeth large, long-crowned, heavily cemented. Upper cheek-teeth with heavy mesostyle, fossettes wide with moderately crinkled enamel borders. Protocone large, strongly compressed laterally, inner border convex. Metaconid-metastylid column of lower cheek-teeth often with wide inner groove.

Of the described species this form most closely approaches *Equus* or *Pliohippus simplicidens* of the Blanco Pliocene. It possibly differs from *Equus simplicidens* in somewhat greater width of the fossettes of the upper cheek-teeth and in the greater anteroposterior diameter of the protocone. The form of the protocone is not fully shown on Cope's figure of the type specimen of *E. simplicidens*, but this pillar is restored by Cope and Gidley as relatively shorter than in the Coalinga species. According to Gidley the teeth of *E. simplicidens* have the appearance of being comparatively short-crowned. The lower teeth referred to *E. simplicidens* are characterized by the angular nature of the groove on the inner side of the metaconid-metastylid column. In a specimen, no. 21333, from North Coalinga this groove is rather sharply angular. In specimen no. 21332 the groove is wider and approaches the form seen in *Equus*.



Figs. 9a and 9b. *Equus* or *Pliohippus*, sp. M¹, no. 21330, natural size. From upper Etchegoin beds, North Coalinga region, California. Fig. 9a, oclusal view; fig. 9b, inner view.

Figs. 10a and 10b. *Equus* or *Pliohippus*, sp. P¹?, no. 21331, natural size. From upper Etchegoin beds, North Coalinga region, California. Fig. 10a, oclusal view; fig. 10b, outer view.

Fig. 11. *Equus* or *Pliohippus*, sp. M₃, oclusal view. No. 21333, natural size. From upper Etchegoin beds, North Coalinga region, California.

Figs. 12a and 12b. *Equus* or *Pliohippus*, sp. P₄?, no. 21332, natural size. From upper Etchegoin beds, North Coalinga region, California. Fig. 12a, oclusal view; fig. 12b, inner view.

The occurrence of this species in the upper portion of the Etchegoin formation shows the existence of a relatively advanced type of horse in the California region, at a time near middle Pliocene.

As nearly as can be determined from the fragmentary material available this species is intermediate between advanced *Pliohippus*-like forms and *Equus*. The internal wall of the protocone is convex, instead of concave, as normally the case in *Equus*, but the anterior end of the protocone is scarcely extended anteriorly beyond the isthmus uniting protocone with protoconule. If the characters of this form are satisfactorily represented in the specimens at hand, and only one form is represented, the species would seem to furnish a transition between *Equus* and *Pliohippus*.

No name is given to this form at present as more and better material is desired before final estimation of the characters is made.

Transmitted October 23, 1915.

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CORALS FROM THE CRETACEOUS AND
TERTIARY OF CALIFORNIA
AND OREGON

BY

JORGEN O. NOMLAND

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CORALS FROM THE CRETACEOUS AND TERTIARY OF CALIFORNIA AND OREGON

BY

JORGEN O. NOMLAND

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INTRODUCTION

Although several species of corals have been described from the Pacific Coast Cretaceous and Tertiary, the members of this group have been used only to a limited extent for correlation purposes. The present paper is an attempt to present a discussion of the Pacific Coast corals in such form that this group may be of larger use to the palaeontologist and to the stratigraphic geologist. A number of new species of West Coast corals available to the writer in various collections are here described.

TABLE SHOWING STRATIGRAPHIC POSITION OF PACIFIC COAST CORALS

		Horizons				
		Lower	Middle	Upper		
PLEISTOCENE	{	Caryophyllia arnoldi Vaughan ⁴	×	×	×	
		Caryophyllia pedroensis Vaughan ⁴	×	×	×	
		Paracyathus pedroensis Vaughan ⁴	×	×	×	
PLIOCENE	{	Astrangia coalingensis Vaughan ⁵ .....	....	×	....
		Astrangia insignifica, n. sp. ....	....	....	×
		Caryophyllia californica Vaughan ⁴ .....	....	....	×
		Favia merriami Vaughan ³ .....	....	×	....
		Madripora solida, n. sp. ....	....	×	....
		Stephanocoenia fairbanksi Vaughan ³....	....	×	....
		Stephanocoenia fairbanksi var. colum- naris Vaughan ³ .....	....	×	....
MIOCENE		No described species.				
OLIGOCENE	{	Dendrophyllia hannibali, n. sp. ....	....	×	....
		Siderastrea clarki, n. sp. ....	....	×	....
EOCENE	{	TEJON	Balanophyllia variabilis, n. sp. ....	....	....	×
			Dendrophyllia tejonensis, n. sp. ....	....	×	....
			Flabellum californicum Vaughan ³ .....	....	....	×
			Flabellum(?) merriami, n. sp. ....	×	....	....
			Flabellum remondianum Gabb ^{1, 3, 7}.....	?	....	....
			Goniopora vauhani, n. sp. ....	....	×	....
			Stephanophyllia californica, n. sp.....	×	×	×
			Thamnasteria sinuata, n. sp. ....	×	....	....
			Trochocyathus californica Vaughan ³.....	....	....	×
			Trochocyathus(?) perrini Dickerson ⁶....	....	....	×
	{	MARTINEZ	Trochocyathus stantoni Vaughan ³ .....	....	....	×
			Trochocyathus striatus (Gabb) ^{1, 3}.....	....	?	×
			Trochocyathus imperialis, n. sp. ....	×	....	....
			Turbinolia dickersoni, n. sp.	×	×	×
			Turbinolia pusillanima, n. sp.....	×	....	....
			Flabellum remondianum Gabb ^{1, 3, 7}	×	×	×
			Smilotrochus(?) curtis Gabb ² .....	....	×	....
			Trochocyathus zitteli Merriam ^{3, 7}	×	×	×
CRETACEOUS	{	Haimesiastrea petrosa (Gabb) ^{1, 3}	?	?	?	
		Trochosmilia(?) granulifera Gabb ¹ .....	....	....	×
		Trochocyathus oregonensis, n. sp. ....	....	....	×
		Trochocyathus pergranulatus, n. sp.....	....	....	×

¹ Gabb, W. M., Geol. Surv. Calif., Palaeontology, vol. 1, 1864.² Gabb, W. M., Geol. Surv. Calif., Palaeontology, vol. 2, 1869.³ Vaughan, T. W., U. S. Geol. Surv., Monograph 39, 1900.⁴ Arnold, Ralph, Calif. Acad. Sci., Memoirs, vol. 3, 1903.⁵ Arnold, Ralph, U. S. Geol. Surv., Bulletin 396, 1909.⁶ Dickerson, R. E., Univ. Calif. Publ. Bull. Dept. Geol., vol. 7, no. 12, 1913.⁷ Dickerson, R. E., Univ. Calif. Publ. Bull. Dept. Geol., vol. 8, no. 6, 1914.

The writer is indebted for criticism and advice to Professor J. C. Merriam, who a number of years ago made an extensive study of California corals and first used them for correlating purposes in the Martinez. Acknowledgment is due to Dr. R. E. Dickerson, whose extensive studies in the California Eocene have made a large part of this work possible.

The writer wishes especially to express his gratitude to Dr. T. Wayland Vaughan of the United States Geological Survey for examination of the manuscript and criticism of the palaeontological determinations.

DESCRIPTION OF SPECIES

TURBINOLIA DICKERSONI, n. sp.

Plate 3, figures 5, 6, 7, 8

Type, University of California Department of Palaeontology collections. The type is from locality 1817, near center of sec. 15, T. 18 S, R. 13 E, M. D. B. & M., Fresno County, California.

Corallum conical. Costae 24, prominent, only six reaching the base, of nearly the same thickness at thecal wall and margin, the twelve longer costae appear but slightly widened near the base, margin flattened. Intercostal furrows with double rows of pores, in some of the larger specimens a low ridge appears between the rows on upper portion. Septa corresponding in number to the costae, those of the primary cycle slightly larger at the calicular margin. On lateral faces of septa are numerous rows of granules extending from wall to septal margin. The columella at the calice projects somewhat above the margin of the septa and appears as a six-pointed star, the rays of which are connected to the primary septa. Diameter of corallum, 2.8 mm.; height, 6.7 mm.

Occurrence at University of California localities 692, 1817, Tejon group, Eocene.

This species seems to resemble closely *Turbinolia phareta* Lea, as described by Vaughan. *T. dickersoni* appears to differ, however, in having the costae of nearly the same thickness at the margin and thecal wall, the costae are not so much widened near the base, and the septa are not of uniform size at the peripheral portion of the calice. Also in *T. dickersoni* the rows of septal granules extend the whole distance across the septa, although in some rows interrupted about two-thirds of the distance from the wall.

TURBINOLIA PUSILLANIMA, n. sp.

Plate 3, figures 9, 10

Type from locality 476, in the University of California Department of Palaeontology collections.

Corallum conical, slender. Of the forty-eight costae twenty-four reach only one-third of distance to base, while twelve others seem to disappear near the base. The costae are much narrower where the forty-eight are present. Costal margin acute. Intercoastal furrows narrow, of less width than the costae. Pores present between the costae. The twenty-four septa corresponding to the shortest costae extend only a short distance from the wall. Diameter of corallum, 3.3 mm.; height, about 5.7 mm.

Occurrence at University of California localities 476, 1817, in the lower Tejon group, Eocene.

Turbinolia pusillanima, n. sp., occurs at the type localities of both *Thamnastria sinuata*, n. sp., and *Flabellum(?) merriami*, n. sp., with the faunas listed under these species.

FLABELLUM(?) MERRIAMI, n. sp.

Plate 3, figures 1, 2, 3, 4. Plate 4, figure 17

Type from University of California Department of Palaeontology collections, from locality 1817 on branch of Salt Creek, near center of sec. 15, T. 18 S, R. 13 E., M. D. B. & M., about sixteen miles north of Coalinga, Fresno County, California.

Corallum cuneate near the base, but above compressed zone around corallum near the middle a transverse section is elliptical. Angles at end of longer transverse axis are acute near the base. The twelve well-defined costae have between them thirty-six others of less prominence, which apparently almost disappear before reaching the basal portion. The costae which correspond in number to all the septa are broad and covered with large granules. Intercoastal grooves narrow. Septa occur in four cycles, the septa of the third cycle apparently fused to the second; septal faces granular. A true columella seems to be present. Greater transverse diameter, 5.2 mm.; lesser transverse diameter, 4.5 mm.; height of corallum, 4.6 mm.

Occurrence at University of California locality 1817, lower Tejon group, Eocene.

This species occurs at the type locality with the following characteristic Tejon species: *Trochocyathus imperialis*, n. sp., *Turbinolia dickersoni*, n. sp., *Turbinolia pusillanima*, n. sp., *Cancellaria stantoni* Dickerson, *Conus hornii* Gabb, *Ficopsis remondii* Gabb, *Rimella simplex* Gabb, *Terebra californica* Gabb, *Turritella andersoni* Dickerson, *Turris fresnoensis* Arnold, *Venericardia planicosta hornii* (Gabb).

TROCHOCYATHUS IMPERIALIS, n. sp.

Plate 4, figures 11, 12

Type from University of California Department of Palaeontology collections from locality 1817.

Corallum short, cornute, basal part small and curved in the direction of the lesser transverse diameter. Section cut transversely to longitudinal axis has elliptical outline. Small scar of attachment shown at base. Costae about sixty-four, granular, twelve show stronger development. Between the more prominent costae are three to five of less prominent development, becoming more numerous around upper portion of corallum. In transverse section cut about two-fifths from base, most of the septa of the first three cycles reach the columella. Fourth cycle complete. Pali present inside of first three cycles. Synapticulae which appear to be incomplete present. Columella fascicular. The measurements of the type were as follows: height of corallum, 19.8 mm.; greater transverse diameter, 14.6 mm.; lesser transverse diameter, 13.1 mm.

Occurrence at University of California localities 1817, 1412.

At the type locality this species occurs with *Flabellum*(?) *merriami*, n. sp., and its associated fauna.

TROCHOCYATHUS OREGONENSIS, n. sp.

Plate 4, figures 9, 10

Type from Forty-nine Mine, Jackson County, Oregon.

Corallum elongate, slightly curved in direction of the lesser transverse axis. Transverse section circular to subcircular. Costae forty-eight, rather prominent, granular, rounded, of the same size. Septa corresponding in number to the costae, rather thick, in four cycles of which only the first reaches the columella. Pali well developed, before the first three cycles of septa. Columella strong, fascicular. Greater transverse diameter of corallum, 8 mm.; lesser transverse diameter, 7.7 mm.; height, 29 mm.

Occurrence at Forty-nine Mine, Jackson County, Oregon. According to F. M. Anderson, the fauna from this locality is lower Chico.

TROCHOCYATHUS PERGRANULATUS, n. sp.

Plate 3, figures 16, 17

Type from locality 484, SE $\frac{1}{4}$ of SW $\frac{1}{4}$ sec. 9, T. 1 S, R. 1 E, M. D. B. & M., in University of California Department of Palaeontology collections.

Corallum apparently conical. Transverse section elliptical. Costae forty-eight, granular, rounded, of not very prominent development. Between the costae are an equal number of rows of small granules which do not appear to have corresponding septa. The forty-eight septa are arranged in four complete cycles of six systems. Septal faces granulated. Pali bilobate, granular, before the first three cycles of septa. Columella almost rudimentary, consisting of only very few trabiculae. Greater transverse diameter, 6.7 mm.; lesser transverse diameter, 5.4 mm.; height of corallum perhaps about 14 mm.

Occurrence at University of California locality 484 in the Chico, Cretaceous, on the south side of Mount Diablo, Contra Costa County, California.

MADRIPORA SOLIDA, n. sp.

Plate 5, figures 1, 2

Type in University of California Department of Palaeontology collections from locality 738.

Corallum seeming to branch irregularly. Cross-section of corallites elliptical. Costae distinct, broad, slightly granulate, corresponding in number to the septa. Septa thick, variable in number, lateral faces apparently smooth, the inner edges of the first and second cycles may be fused to others in an asymmetrical arrangement. Columella absent. In the type specimen the corallites vary considerably in size. The cross-section of the smallest but most perfect corallites shown in the figure had the following dimensions: greater diameter, 8 mm.; lesser diameter, 6.5 mm.

Occurrence near the base of the Carrizo formation, Pliocene, from University of California locality 738 on the south side of Coyote Mountain, San Diego County, California.

Three other species of corals from this locality have been named in manuscript by T. W. Vaughan and listed by Ralph Arnold in United States Geological Survey Professional Paper 47. Material in the University of California collections generically the same as given in unpublished manuscript by Vaughan from the same locality is therefore not described in the present paper.

ASTRANGIA INSIGNIFICA, n. sp.

Plate 3, figures 14, 15

Type in University of California Department of Palaeontology collections, from corner Fourth and Broadway streets, Los Angeles, California.

The material at hand consists of a single corroded specimen of slightly elliptical outline. It appears to have been connected to other corallites by a thin basal expansion. No costae are visible; this may perhaps be due to the worn condition of the specimen. Calice shallow. Septa in four cycles, thick, granulate, those of the third cycle fused to the second; the septa of the fourth cycle very small. Columella well developed, vesicular. Altitude of corallite, 2 mm.; maximum latitude, 8.3 mm.

Occurrence in upper Fernando formation, Pliocene, at corner of Fourth and Broadway streets, Los Angeles, California, in material donated to the University of California by J. Z. Gilbert.

SIDERASTREA CLARKI, n. sp.

Plate 5, figures 3, 4

Type from locality 1131, one-half mile SSW of the town of Walnut Creek, Contra Costa County, California. In University of California collections, Department of Palaeontology.

Corallum massive, subrounded. Corallites angular, mostly pentagonal, separated by a prominent wall which is strengthened inside by numerous adjoining synaptacula. Septa about forty-eight, margins apparently dentate, beginning with the third each succeeding cycle is fused to the one that precedes it. Interseptal synaptacula present and are especially well developed in a grouping around the inside of the wall, giving this the appearance of being very heavy. A well-developed columella present. Diameter of calices about 7.7 mm.

Occurrence near base of *Agasoma gravidum* zone, Oligocene, at locality 1131.

A large fauna has been collected at the type locality of this species, among others the following characteristic Oligocene forms: *Agasoma gravidum* (Gabb), *Amiantis mathewsonii* (Gabb), *Ancillaria fishii* Gabb, *Dosinia mathewsonii* Gabb, *Dosinia whitneyi* (Gabb), *Molopophorus gabbi* Dall, *Molopophorus biplicatus* Gabb, *Mytilus mathewsonii* Gabb, *Priscofusius hecoxi* Arnold.

BALANOPHYLLIA VARIABILIS, n. sp.

Plate 4, figures 2, 3, 4, 13

Type from University of California Department of Palaeontology collections, from locality 714, NE $\frac{1}{4}$ of SE $\frac{1}{4}$ sec. 21, T. 1 S, R. 1 E, M. D. B. & M.

Corallum variable in shape from elongate to short cornute, curved in the direction of the lesser transverse axis. Cross-section elliptical to subcircular. Wall strong, vesicles not numerous. Costae granular, rather wide, rounded, with narrow intercostal grooves; on some specimens a tendency is shown to have every fourth costa of more prominent development. Septa in five cycles, lateral faces granulated, thin at calice but becoming thicker as base is approached, third and fourth cycles fused to the third. Columella somewhat fascicular, in some sections cut near the calice, however, the columellar space seems to be traversed largely by extensions of septa of the first three cycles. Greater transverse diameter, 10.7 mm.; lesser transverse diameter, 10.3 mm.; height of corallum, perhaps about 45 mm., but exact height unknown since in the material at hand no complete specimen of the longer variety could be found.

Occurrence at University of California localities 507D, 714, 1853, in the upper Tejon Eocene.

This species, on account of its slight superficial resemblance to *Trochocyathus striatus* Gabb, has heretofore been identified as such by California palaeontologists. *Balanophyllia variabilis*, n. sp., however, seems to occur more commonly in the Tejon group than *T. striatus* Gabb. In one of the old collections at the University of California the two are from the same locality. It is not known to what extent, however, this material can be relied upon.

STEPHANOPHYLLIA CALIFORNICA, n. sp.

Plate 3, figures 11, 12, 13

Type, University of California Department of Palaeontology collections, from locality 716, on south side of Mount Diablo, Contra Costa County, California.

Corallum simple, planoconvex lens-shaped. Base discoidal. Costae ninety-six, of these the first three cycles reach the center, the two last cycles fused to the ones preceding it. Mural pores well defined. Calice convex, marked by a rather deep depression in the center. Septa ninety-six; of these the primary and secondary reach

the columella; tertiary and quaternary are united to the first two cycles. The septa of the fifth cycle are free and very short. Calicular margin and lateral faces of septa granulated. Columella weak. Measurements of the type, which is a rather small specimen, were as follows: Diameter, 7.8 mm.; height of corallum, 2.7 mm.

Occurrence in the Tejon group at University of California localities 692, 716, 719, 734.

DENDROPHYLLIA HANNIBALI, n. sp.

Plate 6, figures 1, 2, 3

Type in palaeontological collections of Stanford University, from locality NP15, near log dam, Porter Creek, Chehalis County, Washington.

Colony branching, forming several vertical series which unite when coming in contact. Calices deep, nearly round, projecting only slightly above surface, apparently arranged in nearly vertical series, about 5 mm. in diameter. Costae distinct, vermicular, granulated, covering the whole surface. Intercostal furrows narrow, perforate. Wall thick, porous but rather dense. Septa about 42–48, thin and fragile near calice, granulated, in four cycles having arrangement characteristic of the genus. Columella weak.

Occurrence at Stanford University locality NP15, middle Oligocene.

It is deemed advisable to incorporate a description of this species in the present paper, although it properly does not belong to the California province.

DENDROPHYLLIA TEJONENSIS, n. sp.

Plate 4, figures 1, 5

Type from University of California Department of Palaeontology collections, from locality 458, on west side of Grapevine Creek, four and one-half miles S 6° W of 1085 B.M., Tejon Quadrangle, California.

Corallum branched, transverse section of corallites elliptical. Costae prominent, perforate, slightly granulate, arranged longitudinally. Intercostal furrows rather wide and have numerous pores. Wall thick, appears to be strengthened by synapticula arranged adjacent to it. Septa numerous, thin, perforate, lateral faces granulate, arranged in five cycles. Columella not very strong, open spongy. Greater transverse diameter of corallite, 8.5 mm.; lesser transverse diameter, 6.4 mm.

Occurrence near middle of type Tejon section, from University of California locality 458, Eocene.

In the type section of the Tejon group from which *Dendrophyllia tejonensis*, n.sp., is described the following species, among others, have been reported: *Amauropsis alveata* Gabb, *Cardium breweri* Gabb, *Ficopsis remondii* Gabb, *Perrisolax blakei* Gabb, *Turritella uvasana* Conrad, *Venericardia planicosta hornii* (Gabb).

THAMNASTERIA SINUATA, n. sp.

Plate 5, figures 5, 6

Type in University of California Department of Palaeontology collections, from locality 476, SW $\frac{1}{4}$ of NW $\frac{1}{4}$ sec. 22, T. 1 S, R. 1 E, M. D. B. & M.

Superior portion of corallum flat, curving down at the margin. Calices nearly round, well defined, very unequally distributed on the calicular surface. Columella well developed. Septa twelve, prominent, lamellar, between those are seen in thin section an equal number not as prominent development. Septa-costae continuous with those of the neighboring calices, show a decided tendency to parallel arrangement. Synapticula appear to be present. Diameter of calices, about 3 mm.

Occurrence in the lower Tejon Eocene, from locality 476, on south side of Mount Diablo, Contra Costa County, California.

In the type locality this species occurs with the following characteristic Tejon species: *Turbinolia pusillanima*, n.sp., *Ficopsis remondii* Gabb, *Leda gabbi* Conrad, *Meretrix hornii* Gabb, *Tellina remondii* Gabb, *Turritella merriami* Dickerson, *Venericardia planicosta hornii* (Gabb).

GONIOPORA VAUGHANI, n. sp.

Plate 3, figures 18, 19

Type in collections of California Academy of Sciences, San Francisco, from locality 101.

Corallum composite, in type incrusting a fragment of *Ostrea*. Corallites crowded into polygonal forms with distinct, shallow, calices. Septa twenty-four, thick, perforate, in three cycles, apparently fused in bilateral arrangement characteristic of the genus. Synapticula very numerous, arranged around the columella so as to appear as rather definite circles. Columella well developed, spongy. Diameter of corallites about 2.7 mm.

Occurrence at California Academy of Sciences locality 101, along sea-cliff about two miles north of Delmar, San Diego County, California. In the Tejon Eocene.

FAMILY GORGONIDAE

The material at hand consists of one imperfect specimen, shown on plate 4, figure 6. This species seems to belong to the gorgonian corals, although the material does not warrant a description. This specimen is from locality 1853, Chico, Marysville quadrangle, California. Material in collections of Department of Palaeontology of the University of California.

Other fragmentary material shown on plate 4, figures 7 and 8, seems to indicate that the coral belongs to the family Gorgonidae. No specific determination could be made, however. From locality 172 of the California Academy of Sciences, in a small bluff in the SW corner of Commercial and Fifth streets, Astoria, Oregon, probably in the Astoria series Oligocene.

TROCHOCYATHUS ZITTELI Merriam

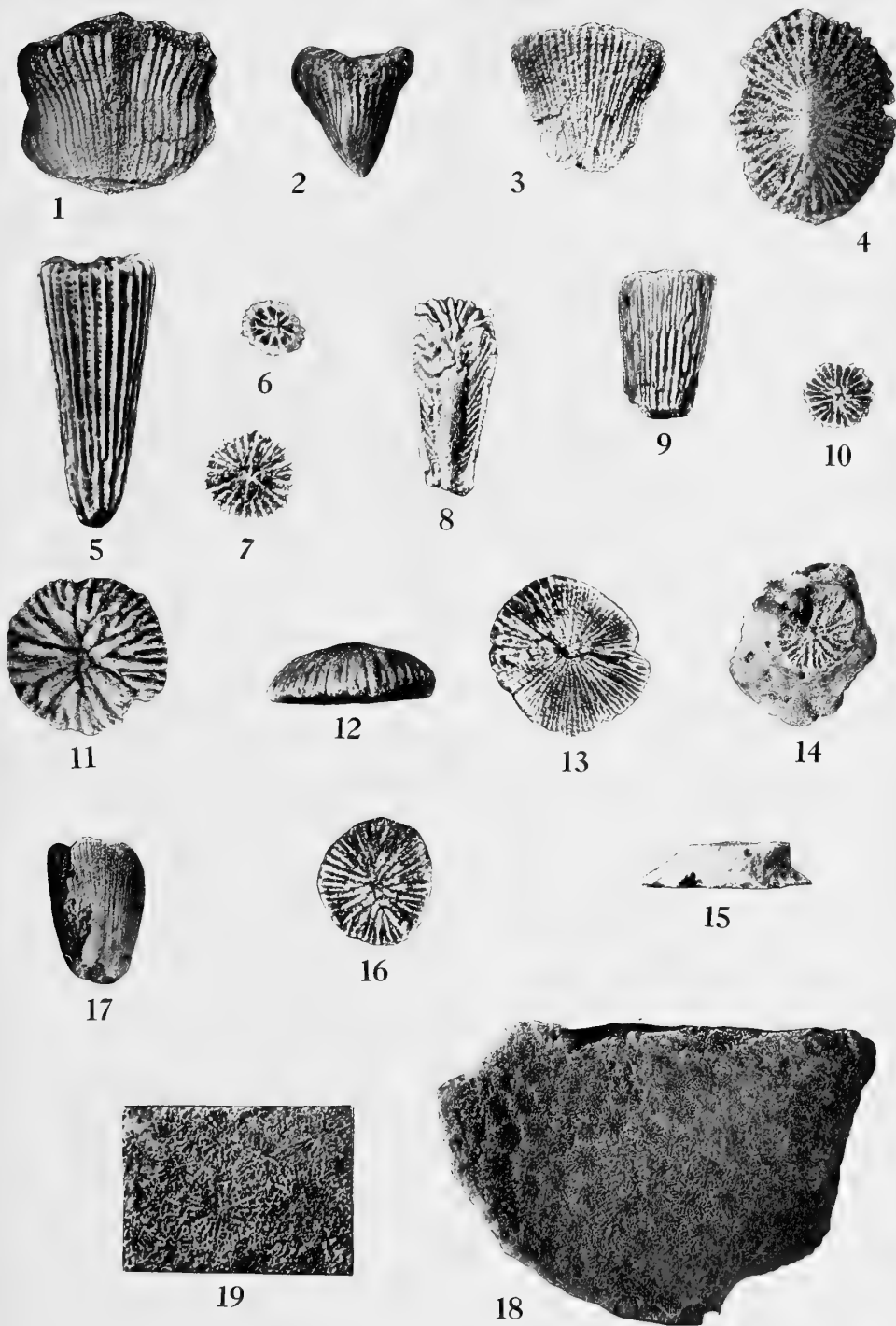
Some forms of *Trochocyathus zitteli* Merriam¹ resemble very closely *Smilotrochus curtis* Gabb.² Scores of specimens of *T. zitteli* have been collected by Merriam, Dickerson, and numerous field classes in palaeontology at the same general locality as that indefinitely given as the type locality of *S. curtis*, but not one specimen of this species has been reported. It is therefore possible that the two are the same. Gabb's type material consisted of only two very imperfect specimens which cannot now be located for comparison, and the evidence seems to be insufficient for placing *T. zitteli* in synonymy with *S. curtis*.

¹ U. S. Geol. Surv., Monograph 39, 1900.

² Geol. Surv. Calif., Palaeontology, vol. 2, 1869.

EXPLANATION OF PLATE 3

- Fig. 1. *Flabellum(?) merriami*, n. sp., upright view of type. $\times 5$.
Fig. 2. *Flabellum(?) merriami*, n. sp., another view of the specimen shown in figure 1. $\times 4$.
Fig. 3. *Flabellum(?) merriami*, n. sp., a slender specimen. $\times 4$.
Fig. 4. *Flabellum(?) merriami*, n. sp., view of base of fig. 3. $\times 5$.
Fig. 5. *Turbinolia dickersoni*, n. sp., upright view of type. $\times 5\frac{1}{2}$.
Fig. 6. *Turbinolia dickersoni*, n. sp., cross-section near middle of small specimen. $\times 4$.
Fig. 7. *Turbinolia dickersoni*, n. sp., calicular view of fig. 5. $\times 5$.
Fig. 8. *Turbinolia dickersoni*, n. sp., showing ornamentation of septal faces. $\times 5$.
Fig. 9. *Turbinolia pusillanima*, n. sp., upright view of imperfect type specimen. $\times 4$.
Fig. 10. *Turbinolia pusillanima*, n. sp., cross-section short distance below calice. $\times 4$.
Fig. 11. *Stephanophyllia californica*, n. sp., calicular view of rather small specimen. $\times 3$.
Fig. 12. *Stephanophyllia californica*, n. sp., side view of specimen shown in figure 11. $\times 3$.
Fig. 13. *Stephanophyllia californica*, n. sp., view of base of specimen shown in figure 11. $\times 3$.
Fig. 14. *Astrangia insignifica*, n. sp., view of calice. $\times 3$.
Fig. 15. *Astrangia insignifica*, n. sp., side view of specimen shown in figure 14. $\times 3$.
Fig. 16. *Trochocyathus pergranulatus*, n. sp., cross-section. $\times 3$.
Fig. 17. *Trochocyathus pergranulatus*, n. sp., upright view of imperfect type. $\times 3$.
Fig. 18. *Goniopora vauhani*, n. sp., general view of corallum. $\times 1\frac{1}{2}$.
Fig. 19. *Goniopora vauhani*, n. sp., view of calices. $\times 3$.

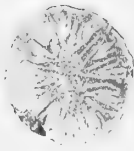


EXPLANATION OF PLATE 4

- Fig. 1. *Dendrophyllia tejonensis*, n. sp., general view. $\times 2$.
Fig. 2. *Balanophyllia variabilis*, n. sp., cross-section some distance below calice. $\times 2$.
Fig. 3. *Balanophyllia variabilis*, n. sp., cross-section near calice. $\times 2$.
Fig. 4. *Balanophyllia variabilis*, n. sp., upright view of short specimen. $\times 2$.
Fig. 5. *Dendrophyllia tejonensis*, n. sp., cross-section of a branch. $\times 3$.
Fig. 6. *Gorgonia* sp., general view. $\times 1\frac{1}{2}$.
Fig. 7. *Gorgonia* sp., general view. $\times 1\frac{1}{2}$.
Fig. 8. *Gorgonia* sp., general view. $\times 1\frac{1}{2}$.
Fig. 9. *Trochocyathus oregonensis*, n. sp., cross-section. $\times 3$.
Fig. 10. *Trochocyathus oregonensis*, n. sp., upright view of type. $\times 1\frac{1}{3}$.
Fig. 11. *Trochocyathus imperialis*, n. sp., general view. $\times 2$.
Fig. 12. *Trochocyathus imperialis*, n. sp., cross-section some distance above base. $\times 2$.
Fig. 13. *Balanophyllia variabilis*, n. sp., general view of type. $\times 1\frac{1}{3}$.
Fig. 14. *Flabellum californicum* Vaughan, specimen from type locality. $\times 2$.
Fig. 15. *Flabellum californicum* Vaughan, cross-section. $\times 2$.
Fig. 16. *Flabellum californicum* Vaughan, showing specimen not curved in plane of shorter transverse axis. $\times 2$.
Fig. 17. *Flabellum(?) merriami*, n. sp., cross-section. $\times 4$.



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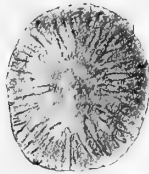
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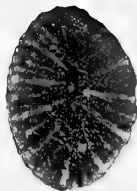
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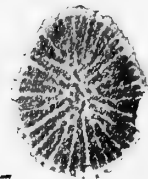
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EXPLANATION OF PLATE 5

- Fig. 1. *Madripora solida*, n. sp., general view. $\times 1\frac{1}{3}$.
Fig. 2. *Madripora solida*, n. sp., cross-section of one of smaller branches. $\times 2$.
Fig. 3. *Siderastrea clarki*, n. sp., general view of corallum. $\times 1\frac{1}{3}$.
Fig. 4. *Siderastrea clarki*, n. sp., view of corallites. $\times 2$.
Fig. 5. *Thamnasteria sinuata*, n. sp., general view of fragment. $\times 1\frac{1}{3}$.
Fig. 6. *Thamnasteria sinuata*, n. sp., transverse section across corallites. $\times 2$.



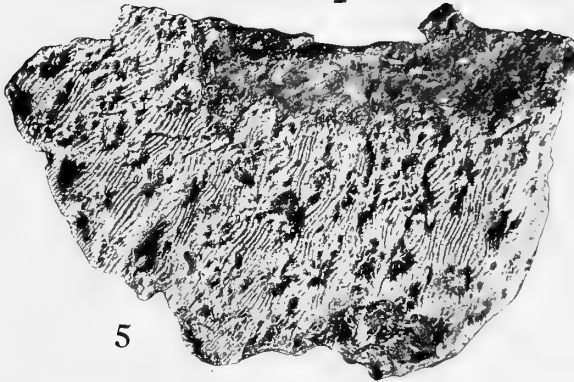
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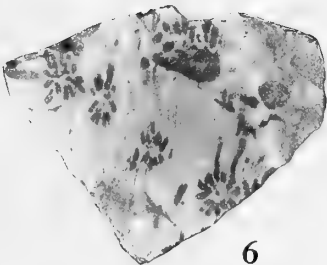
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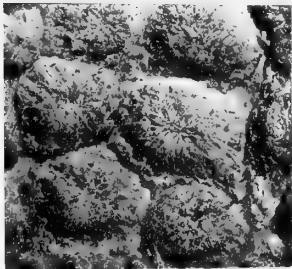
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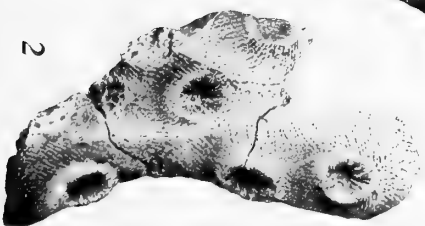
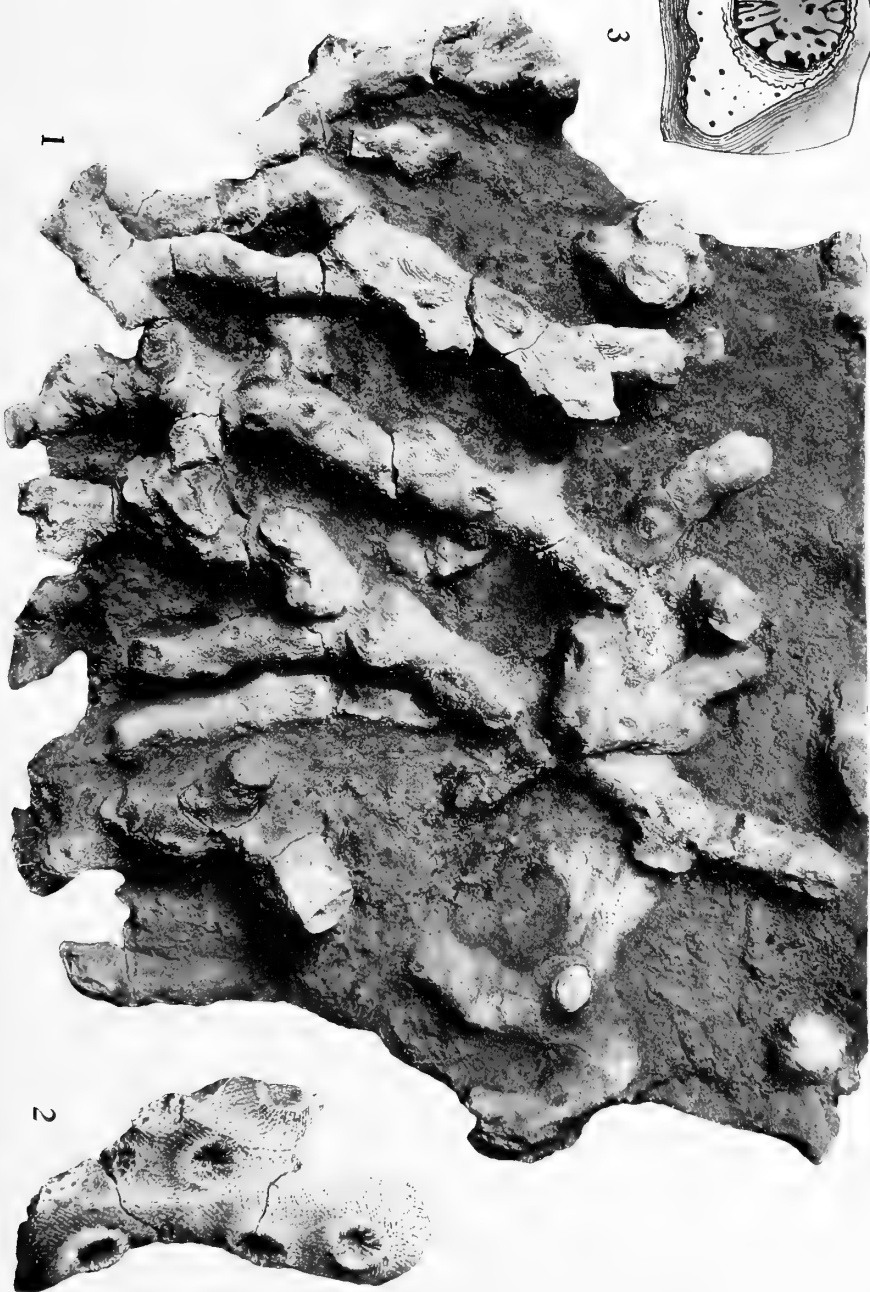
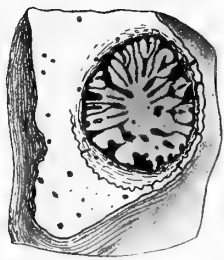
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4

EXPLANATION OF PLATE 6

- Fig. 1. *Dendrophyllia hannibali*, n. sp., general view showing branching. $\times \frac{1}{2}$.
Fig. 2. *Dendrophyllia hannibali*, n. sp., view of a branch showing costal development. $\times 1$.
Fig. 3. *Dendrophyllia hannibali*, n. sp., cross-section below calice. $\times 3$.



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VERTEBRATE FAUNAL ZONES OF THE
JACALITOS AND ETCHEGOIN FOR-
MATIONS IN THE NORTH
COALINGA REGION,
CALIFORNIA

BY

JORGEN O. NOMLAND



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Issued January 20, 1916

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JORGEN O. NOMLAND

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INTRODUCTION

In a recent publication by Professor J. C. Merriam¹ attention was called to the finding of vertebrate fossils in the Jacalitos and Etchegoin formations near Coalinga, Fresno County, California. It was also pointed out that these vertebrate remains have been found in zones having a quite definite relationship to the invertebrate faunal zones

¹ Merriam, J. C., Tertiary Vertebrate Faunas of the North Coalinga Region, Trans. Amer. Philos. Soc., vol. 22, part 3, 1915.

in this region. Since this occurrence offers a somewhat unusual opportunity for the comparison of the invertebrate and vertebrate time-scales of California in the upper Miocene and lower Pliocene and of the invertebrate faunal zones of the western with those of the eastern part of the continent, a more or less detailed description is here presented.

The locality at which this relationship of vertebrate and invertebrate faunal zones has been studied is located about nine miles north-northeast of Coalinga and east and northeast of the small town of Oilfields. The eastern foothills of the Coast Ranges here show exposures of the Jacalitos and Etchegoin formations. The Tulare is exposed only to a very limited extent at Anticline Ridge. The region examined forms a rectangular strip extending in a north and south direction and has an areal extent of somewhat more than a half township.

HISTORICAL

The first paper dealing definitely with this region was published by F. M. Anderson.² This was followed a few years later by another publication on this region by the same author.³ According to Anderson, the later Neocene may here be divided into the Coalinga beds and the Etchegoin beds. The latter were subdivided into the Etchegoin sands and San Joaquin clays. The type section of his Etchegoin beds is located in the neighborhood of the old John Etchegoin ranch about fifteen miles northeast of Coalinga. A persistent fossil horizon is mentioned as occurring somewhere near the base. This was later named the Glycymeris zone by Arnold and Anderson and used as the typical basal Etchegoin in their mapping of the Coalinga field.

In a bulletin published by Ralph Arnold and Robert Anderson⁴ the Coalinga beds of F. M. Anderson were divided into three formations, the lowest of which was called the Vaqueros, above this the Santa Margarita, and uppermost the Jacalitos. The Jacalitos formation was defined as being above the basal gravels and fossil wood zone overlying the fossiliferous Santa Margarita. At the top the Jacalitos was defined as being below the Glycymeris zone at the base

² Anderson, F. M., *A Stratigraphic Study in the Mount Diablo Range of California*, Proc. Calif. Acad. Sci., 3rd ser. vol. 2, no. 1, 1905.

³ Anderson, F. M., *A Further Stratigraphic Study in the Mount Diablo Range of California*, Proc. Calif. Acad. Sci., 4th ser., vol. 3, 1908.

⁴ U. S. Geol. Surv. Bull. 398, 1910.

of the Etchegoin. In this paper Arnold and Anderson stated that for the Etchegoin, "The upper limit is not defined for the hills north of Coalinga owing to the indefiniteness of the line between the Etchegoin and Tulare there." As will be shown in this paper, the Mya zone, which corresponds to the uppermost Etchegoin in other parts of this district, and also other corresponding zones have been discovered north of Coalinga in the typical section of that formation.

JACALITOS AND ETCHEGOIN NORTHEAST OF COALINGA

The base of the Jacalitos as defined here is the first gravel above the fossiliferous Santa Margarita formation. This is taken from the detailed mapping of J. H. Ruckman,⁵ according to whom some of the thick beds of gravel seen near the anticline become thinner and also more sandy and finally shaly on being traced northward. Ruckman also shows that the basal gravels unconformable above the Santa Margarita consists of a member somewhat lower than the one mapped as such by Arnold and Anderson. In these basal gravel beds we find a large amount of silicified wood and gypsum. Immediately above this occurs a member of brown, red, gray, and otherwise highly colored clays. Leaf impressions are abundant. These conditions seem to indicate that these beds are terrestrial deposits.

About two hundred feet above the base we have other gravel beds which seem to have been mapped as the basal Jacalitos by Arnold and Anderson. Possibly these beds may be unconformable with the underlying clays. It was in this zone that Arnold and Anderson reported finding a tooth of *Pliohippus*. From these gravels upward to the top, the Jacalitos consists largely of soft yellowish clays with interbedded vivianitic sandstone and conglomerate.

The exact relations of the Jacalitos and Etchegoin as mapped by Arnold and Anderson in the field north of Coalinga are a matter of doubt, since we have in the northern field two series of beds apparently conformable, in the lower of which no invertebrate fauna has been found. The two series of beds in the southern part of the district with which the Jacalitos and Etchegoin here described have been correlated are, however, said to be unconformable and to have faunas which are somewhat different.

In the basal Etchegoin the low, dark bluish-colored hills show exposures of a coarse-grained, slightly consolidated, vivianitic sand-

⁵ Publication in press.

stone. The texture is uniform in the same members of the beds. Different members may, however, be very different in texture as well as in other characteristics. The lowest beds have a dip of 10° E, the dip becoming slightly less in the upper part of the formation.

At a short but variable distance above the Glycymeris zone, or lowermost Etchegoin, an unconformity was traced from sec. 1, T. 19 S, R. 15 E, southward to Anticline Ridge, a distance of about seven miles. The beds below could be traced to the beds above, being cut off by the unconformity. At one locality where the beds below the unconformity were composed of hard clay, inclusions of this clay were found in the sandstone above. No difference in dip could be discovered between the beds above and below the irregular contact. Locally the member above has a basal conglomerate as at Anticline Ridge, where it has a thickness of fifteen feet or more and has been used as a gravel pit. A good exposure may be seen at sec. 1, T. 19 S, R. 15 E, where a fault block has brought into view the unconformity but not the fossiliferous zone beneath. As seen by the description given, this unconformity may be of only local importance. This also seems to be shown by the finding of the same species of horse both above and below.

Beginning a short distance above the basal beds and continuing upwards for several hundred feet a striking characteristic cross-bedding has its maximum development. These beds are made up almost entirely of a coarse-grained vivianitic sandstone. The cross-bedded members are as a rule abruptly cut off both above and below by clay strata or beds of conglomerate which have a dip of 10° E. Except that the material of which the cross-bedded sandstones are composed seems to become progressively finer in the upper portion, these beds seem to have been deposited under conditions somewhat similar to those under which the parallel stratified beds beneath were deposited. The beds below contain marine fossils.

In going upward from the basal Etchegoin beds no member could be followed along the strike continuously over one or two miles until thirteen hundred feet above the base. At that position occur two bands of a white ashy shale mixed in some places with a fine white sand. The fossils found in the upper of these bands show that this corresponds to the Mya zone of the uppermost Etchegoin in the Kettleman Hills and the Kreyenhagen Hills as described by Arnold and Anderson. This zone was traced for eight or nine miles as a low

ridge in the outermost foothills. At one locality about fifty feet below the upper shale band a bed of porous, white, fine-grained tuff with a small quantity of interstratified quartz sand was found. In the upper half of the formation, on approaching the anticline from the north, several other shale members together with additional invertebrate zones make their appearance. In this region relatively little vertebrate material is present. This may perhaps be due to deeper water here than farther north during deposition.

INVERTEBRATE FAUNAL ZONES

No invertebrate fossils have thus far been found in the seventeen hundred feet of sands, gravels, and clays mapped as Jacalitos. Stratigraphically, however, these beds seem to form a continuous, conformable series, at least from Arnold and Anderson's basal gravels, up to the unconformity above the *Glycymeris* zone. This zone can be traced almost continuously for nine or ten miles. About forty feet above it another zone appears at intervals. South of Oilfields for a short distance *Glycymeris coalingensis* Arnold is found in great abundance. On going north, however, *Tamiosoma*, cf. *gregaria* Conrad and *Mulinia densata* Conrad are the more common species.

The invertebrate fauna of the *Glycymeris* zone and the one a short distance above it consists of the following species:

ECHINODERMATA

Echinarachnius gibbsii Rémond

CIRRIPEDIA

Balanus, sp.

Tamiosoma, cf. *gregaria* Conrad

PELECYPODA

Area trilineata Conrad

Margarita johnsoni Arnold

Cardium corbis Martyn

Panopea generosa Gould

Cryptomya ovalis Conrad

Paphia staleyi Gabb

Cryptomya quadrata Arnold

Pecten wattsi Arnold

Glycymeris coalingensis Arnold

Pecten oweni Arnold

Glycymeris septentrionalis Mid-dendorf

Pecten estrellanus Conrad, var. *terminus* Arnold

Macoma inquinata Deshayes

Phacoides, sp.

Macoma nasuta Conrad

Sanguinolaria nuttalli Conrad

Macoma secta Conrad

Saxidomus nuttalli Conrad

Metis alta Conrad

Schizothaerus nuttalli Conrad

Modiolus, sp.

Solen sicarius Gould

Mulinia densata Conrad

Spisula albaria Conrad

Mytilus coalingensis Arnold

Spisula coalingensis Arnold

Ostrea atwoodi Gabb

Tellina bodegensis Hinds

GASTROPODA

<i>Calliostoma coalingensis</i> Arnold	<i>Nassa californica</i> Conrad
<i>Calliostoma ethegoinensis</i> , n. sp.	<i>Neverita convexa</i> , n. sp.
<i>Calyptrea filosa</i> Gabb	<i>Olivella biplicata</i> Conrad
<i>Columbella</i> (<i>Astyris</i>) <i>richthofeni</i> Gabb	<i>Pleurotoma coalingensis</i> Arnold
<i>Crepidula onyx</i> Sowerby	<i>Thais lamellosa</i> Gmelin
<i>Lunatia</i> , sp.	<i>Thais kettelmanensis</i> Arnold
	<i>Turritella vanvlecki</i> Arnold

About two miles north of Anticline Ridge and six hundred feet stratigraphically above the Glycymeris zone occurs another zone characterized by a great abundance of a thin variety of *Echinarachnius gibbsii* Rémond. The fossils are found in a bed of yellowish, sandy clay which is only a short distance above the highest vivianitic sandstone that occurs at this locality. This seems to correspond to the Lower Middle zone of the Etchegoin as mapped by Arnold and Anderson in the southern part of the district. The following species have been found at this horizon:

<i>Crepidula onyx</i> Sowerby	<i>Mytilus</i> , cf. <i>edulis</i> Linne
<i>Cryptomya quadrata</i> Arnold	<i>Mytilus coalingensis</i> Arnold
<i>Echinarachnius gibbsii</i> Rémond, thin variety.	<i>Olivella biplicata</i> Conrad
<i>Lunatia</i> , sp.	<i>Saxidomus nuttalli</i> Conrad
<i>Macoma inquinata</i> Deshayes	<i>Schizothaerus nuttalli</i> Conrad
<i>Metis alta</i> Conrad	<i>Solen</i> , sp.

A few hundred feet above the zone last described another zone was found with vertebrate material at the same locality. The invertebrate material, being in a very poor state of preservation, could not be identified except as follows:

<i>Area trilineata</i> Conrad	<i>Neverita</i> , sp.
<i>Macoma</i> , sp.	<i>Pecten</i> , sp.
<i>Mytilus</i> , sp.	

About one hundred feet below the *Mya japonica* zone near the anticline a band of white shale occurs in which are found a large number of fragments of *Pecten nutteri* Arnold. The presence of this species and its stratigraphic position seem to place this as the equivalent of the Upper Middle beds, or the *Pecten coalingensis* zone south of Coalinga. The following species were collected:

<i>Area trilineata</i> Conrad	<i>Cancer</i>
<i>Calyptrea filosa</i> Gabb	Fish vertebrae
<i>Pecten nutteri</i> Arnold	

The beds in which *Mya japonica* Jay occurs consist of an ashy shale. Gypsum and silicified wood are abundant. The peculiar, so-called bulbous fish growths of many variable shapes form an almost continuous zone here. One of these seemed to be a somewhat water-worn canine tooth. The fauna represents littoral conditions. The indications therefore, seem to be that the Etchegoin sea was growing shallow before passing into the Tulare fresh-water or alluvial beds, as shown by exposures in the Kettleman Hills directly above the *Mya* zone. The fauna of this zone consists of:

Glycymeris septentrionalis Mid-	Macoma, sp.
dendorf	Mya japonica Jay
Littorina mariana Arnold	Solen sicarius Gould

Immediately below this, or between the two shale bands, the following forms were found:

Mulinia densata Conrad	Tamiosoma, cf. gregaria Conrad
------------------------	--------------------------------

VERTEBRATE FAUNAL ZONES

As has already been mentioned, a large quantity of fossil leaves and petrified wood is found in the highly colored, perhaps land-laid beds mapped as basal Jacalitos. This collection may, when carefully studied, assist in determining the age of this formation. In these beds fossil remains of the three-toed horse *Neohipparion molle* Merriam were found.

The finding of *Pliohippus*? in the gravels two hundred feet above the basal Jacalitos, or in the bed mapped by Arnold and Anderson as their lowest Jacalitos member, has already been mentioned in this paper.

Above this no invertebrate or vertebrate fossils have thus far been found until reaching the *Glycymeris coalingensis* zone, or lowest Etchegoin. The *Pliohippus* stage of the development of the horse is represented here in the basal beds and a few hundred feet upwards. This zone has therefore been called the *pliohippus coalingensis* zone by Professor Merriam.

Beginning near the Lower Middle invertebrate zone and extending upward to the uppermost Etchegoin or *Mya* zone, we have the occurrence of mastodon, two very different species of camel, a member of the deer family, and a large horse much like *Equus* or possibly *Pliohippus*. The very recent aspect of at least a part of this fauna has cast doubt upon the occurrence of these fossils, and the question has been raised whether these remains may not occur in terrace material.

The larger streams show evidences in the lower valleys of at least three periods of terracing, perhaps largely due to aggraded streams. Although in the region to the north, as at Domengine Creek and Cantua Creek, there are evidences of far higher terraces, in the region where the vertebrate remains are found there are now no evidences of terraces and if terrace deposits were ever present they are now completely removed from the bare outcrops of Etchegoin strata. None of the terrace material characterized by fragments of *Ostrea titan* Conrad and *Pecten estrellanus* Conrad brought from the Santa Margarita and none of the red and black pebbles brought from the Chico are here present. At one locality several horse teeth were found near the top of a sharp hill with very evident outcropping strata of a compact resistant shale. It seems odd that, if general terracing of the region has taken place and nearly all of the deposits have been removed, we do not find this fauna upon the lower part of the Etchegoin or at the localities in the Jacalitos which are of no greater elevation. On the contrary, the bone fragments in some places seem to occur along zones following the outcropping strata, and collecting could be done with success only by following these beds.

SUMMARY

As has been stated, the faunal zones of the Etchegoin corresponding to similar zones in the southern part of this district appear to occur here in the type section of the formation. The uppermost of these corresponds to the Mya zone, which in the Kettleman Hills is immediately below the Tulare formation. Hence we apparently have exposures of the complete Etchegoin section in this area. Near the base of the Etchegoin an unconformity has been found which perhaps may prove to be of some importance when a wider and more careful study has been made. Vertebrate faunal zones have been found in both the Jacalitos and Etchegoin formations. These have a relation to the invertebrate faunal zones that tends to throw light upon the interrelation of the two faunal time-scales of the Pacific Coast. As shown by the studies of Professor Merriam,⁶ the evidence seems to indicate that the invertebrate horizons referred to the upper Miocene and lower Miocene have been placed somewhat lower than the corresponding horizons of the eastern part of this continent and of Europe.

⁶ Merriam, J. C., Tertiary Vertebrate Faunas of the North Coalinga Region, Trans. Am. Philos. Soc., vol. 22, part 3, Philadelphia, 1915

SECTION SHOWING STRATIGRAPHIC POSITION OF INVERTEBRATE AND VERTEBRATE
FAUNAL ZONES IN THE JACALITOS AND ETCHEGOIN FORMATIONS NEAR COALINGA

TULARE	{			
	{	Mya Zone	Shale, gypsum, tuff, clays.	Occurrence of <i>Equus</i> or <i>Pliohippus</i> , mastodon, camels, etc.
		Upper Middle Zone	Yellow clays	
ETCHEGOIN 1300 feet	{	Lower Middle Zone	Cross-bedded vivianitic sandstone, clays, conglomerate.	
	{	Glycymeris Zone	Unconformity.	<i>Pliohippus coalingensis</i> (Merriam).
			Yellow clays.	
			Vivianitic sandstone, clays.	
JACALITOS 1700 feet	{		Colored clays, sands.	
			Conglomerate.	<i>Pliohippus?</i>
			"Red beds."	
SANTA MARGARITA	{		Unconformity	<i>Neohipparion molle</i> Merriam.

DESCRIPTION OF NEW SPECIES
CALLIOSTOMA ETCHEGOINENSIS, n. sp.

Plate 7, figure 3

Type from University of California locality 2096 in the Etchegoin formation, northeast of Oilfields, California.

Shell conical, apex subacute. Whorls about five, with nearly straight sides, the angle of body-whorl very sharp and base flattish. The sculpture on the sides of the whorls consists of three or four revolving ridges, the bottom one being the smallest, and fine intercalaries between each pair of the upper two or three; the upper

surface of whorls has four spiral ribs, of which the posterior is much more prominent, this giving the top a tabulate aspect which is not due to impression at suture; at the base are a number of slightly nodose, spiral ribs of which the two inner are the most prominent. Suture slightly impressed, between two strong revolving ridges. All the major ribs and intercalaries are nodose.

Height, 16.2 mm.; maximum diameter, 16.7 mm.

This species resembles rather closely *Calliostoma coalingensis* Arnold, also found in this district. In *Calliostoma ethegoinensis*, n. sp., however, all the ribs have well-developed nodes, and the tabulate upper surface of whorls is not at the suture but extends from a strong ridge immediately below suture to the upper ridge on sides of whorls.

PURPURA TURRIS, n. sp.

Plate 7, figure 4

Type in collections of University of California Department of Palaeontology, from locality 2110.

Shell thick, medium in size, spire and canal short, turreted; whorls about six, shouldered, channeled immediately below suture; mouth subovate, outer lip much thickened; canal open, inclined slightly to the left; body-whorl ornamented by about seven revolving ribs, of which four are more prominent, of the ten longitudinal varices on body-whorl of type two are heavier and lamellar.

Height, 40 mm.; maximum diameter, 28.5 mm.

Occurrence in the lower Etchegoin formation, west of Coalinga, at University of California locality 2110.

NATICA (NEVERITA) CONVEXA, n. sp.

Plate 7, figures 1, 2

Type from University of California locality 2091.

Shell slightly ovate with elevated spire; whorls about four, strongly convex, becoming somewhat flattened near the top, giving the whorls a slightly tabulate appearance; near the mouth the lower part of body-whorl curves downward considerably; surface covered by numerous oblique incremental lines; suture distinct, not appressed; umbilical

callus large, rather prominent, completely covering the umbilicus, no groove present on its surface.

Height of type, 17.8 mm.; greatest diameter, 16.5 mm.

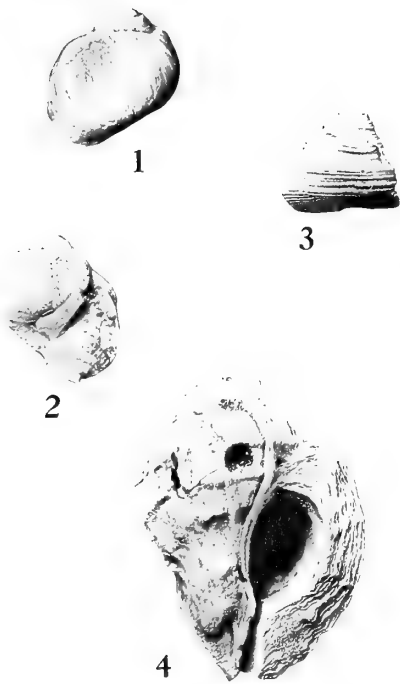
Occurrence at University of California localities 2091, 2093, 2096, in the Etchegoin formation northeast of Coalinga, California.

This species is distinguishable from *Natica reclusiana* Petit, which is also found in this district, by the convexity of the whorls, the tabulate appearance, and the downward curving of the body-whorl near the mouth.

Transmitted February 26, 1915.

EXPLANATION OF PLATE 7

- Fig. 1. *Natica (Neverita) convexa*, n. sp., front view, natural size.
Fig. 2. *Natica (Neverita) convexa*, n. sp., posterior view, natural size.
Fig. 3. *Calliostoma etchegoinensis*, n. sp., posterior view, natural size.
Fig. 4. *Purpura turris*, n. sp., natural size.



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BY

LOYE HOLMES MILLER

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A REVIEW OF THE SPECIES *PAVO* *CALIFORNICUS*

BY

LOYE HOLMES MILLER

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INTRODUCTION

At the close of the first excavation of the University of California at Rancho La Brea, there were found among the avian remains resulting from this work a small number of very imperfect specimens representing a large gallinaceous bird of unknown affinities. Later in the same locality, the perfect tarsometatarsus of an adult male of presumably the same species was taken by the present writer and a second specimen of the same bone was generously donated by Mr. E. J. Fischer of Los Angeles. These perfect specimens constituted the material from which was described the new species *Pavo californicus* Miller¹ and the type specimen was deposited in the palaeontological collections at the University of California.

At the time the original description was published, *Meleagris gallopavo* (domestic) was the only meleagrine available for comparison. Recourse was had to the extensive monograph of Milne-

¹ Miller, L. H., Univ. Calif. Publ. Bull. Dept. Geol., vol. 5, no. 19, p. 285, 1909.

Edwards² in which he figures and compares *Meleagris*, *Pavo*, and other phasianids. Also some measurements were made upon the shank of a live male *Pavo cristatus*. With the material at hand it seemed proper to refer the fossil species to the genus *Pavo* despite the somewhat startling nature of such announcement.

After the lapse of some time the University had opportunity to make further and much more extended exploration of the asphalt beds, which resulted in the assembling of a representative series of *Pavo* remains, including most of the characteristic bones and a goodly series of the type segment, the tarsometatarsus. Related Recent species are also more perfectly represented. There are at hand complete skeletons of *Pavo cristatus* in native phase, *Meleagris ocellatus*, both sexes, and most of the skeleton of *Meleagris gallopavo* in native phase.³ An opportunity to examine a large series of skeletons of the Recent *Meleagris gallopavo* in native phase at Yale University was afforded the writer by Professors Schuchert and Lull of that institution. In the presence of this additional material both Recent and fossil it seems proper to review the entire question of the relationships of the extinct species from Rancho La Brea, described in 1909 as *Pavo californicus*.

DETAILED COMPARISON

Tarsometatarsus.—A splendid series of twenty-five complete tarsometatarsi now represent *Pavo californicus* in the collections of the University of California. In considering this series of the type segment, there is noticeable a marked degree of variation in the total length and in the actual elevation of the spur core; the relative elevation of the spur, however, shows but little variation, remaining between forty and forty-one per cent of the total tarsal length. The age of the individual is judged from the length and the strength of the spur core and from the degree of ossification of the plantar tendons. With these criteria as a basis of age determination, it is seen that the length of tarsus is not directly proportional to age. The longest tarsometatarsus has the weakest spur and the strongest spur is found on the shortest adult bone.

² Milne-Edwards, A., Oiseaux fossiles de la France, Paris, 1867-77.

³ For the valuable *Meleagris* material grateful acknowledgment is made to Dr. L. A. Test of Missouri State School of Mines and to the National Museum of Mexico.

The stoutness of the shaft is remarkably constant for a praecocial bird of the size of *Pavo*. The extremes of transverse diameter in birds old enough to bear the spur are only 0.7 mm. apart.

One of the characters by which *Pavo* is set off from *Meleagris* is the presence of an incipient third ridge between the inner and the outer ridges of the hypotarsus. This ridge is almost entirely wanting even in old specimens of *Meleagris gallopavo* but is present in *Pavo californicus* before the ossification of the plantar tendons, and is equally marked in both sexes. This incipient ridge is but faintly indicated in *M. ocellatus* in both sexes, although both specimens at hand are fully adult. With respect to this character, the four species under consideration fall into the following progressive series: *M. gallopavo*, *M. ocellatus*, *P. cristatus*, and *P. californicus*. The outer ridge of the hypotarsus is short and is dropped downward in *Meleagris*, is longer and less prominent in *Pavo cristatus*, is longest and most prominent in *P. californicus*. In the development of the spur and in the shape of the spur core, *P. californicus* resembles *Meleagris ocellatus* more than it does *Pavo cristatus*. In the elevation of the toes, the fossil form is more like *M. ocellatus* than like *P. cristatus*. In elevation of the spur it is almost identical with *P. cristatus* and far removed from *M. ocellatus*.

From the study of this bone only, the fossil species would seem as far removed from either living species as the two living species are from each other.

In the original description of *Pavo californicus*, the statement was made that the sexes were alike except for the presence or absence of the spur core. This statement was based upon the erroneous conclusion that the fossil species followed *Meleagris gallopavo* in developing the spur as early as the ossification of the plantar tendons. A young male specimen with the plantar ridge present but with the spur lacking was identified as an adult female. With the present series before one the error of this conclusion is easily noted.

Tibiotarsus.—It will be seen from the above study of the tarso-metatarsus in the Recent *Pavo* and the ocellated turkey that, while the bones in the two species are almost identical in length, the shaft of the bone is appreciably heavier in *Pavo*. The exact reverse is found to be true in comparing the tibiotarsi of the same two individuals. The total length of this segment in the peacock is 197.7 mm., in the ocellated turkey it is 187. The transverse diameter of the shaft is 8.5 mm. in the former and 9 mm. in the latter.

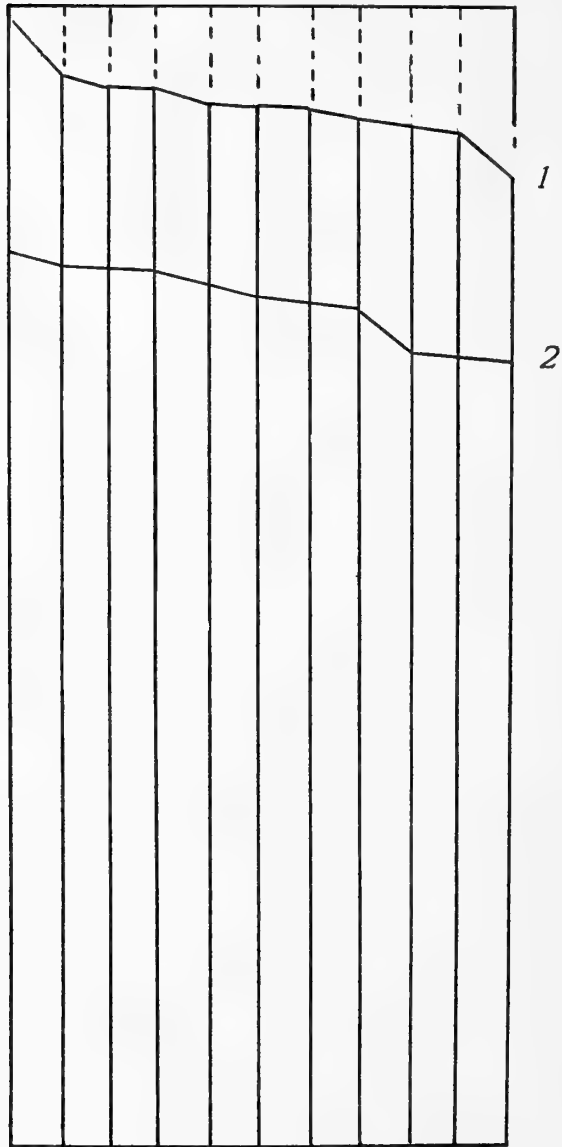


Fig. 1. *Parapavo californicus*. Tarsometatarsus. 1, Graph showing total length in a series of males, natural size; 2, the same for a series of females. Heavy vertical lines represent actual lengths of specimens.

Viewed from in front these bones show the cnemial crest in *M. ocellatus* more abruptly thrust over toward the outside and the distal condyles less widely separated, although the tunnel under the osseous bridge is larger. In all these respects, the affinities of the fossil species are with *Pavo* rather than with *Meleagris*. Beyond these points there

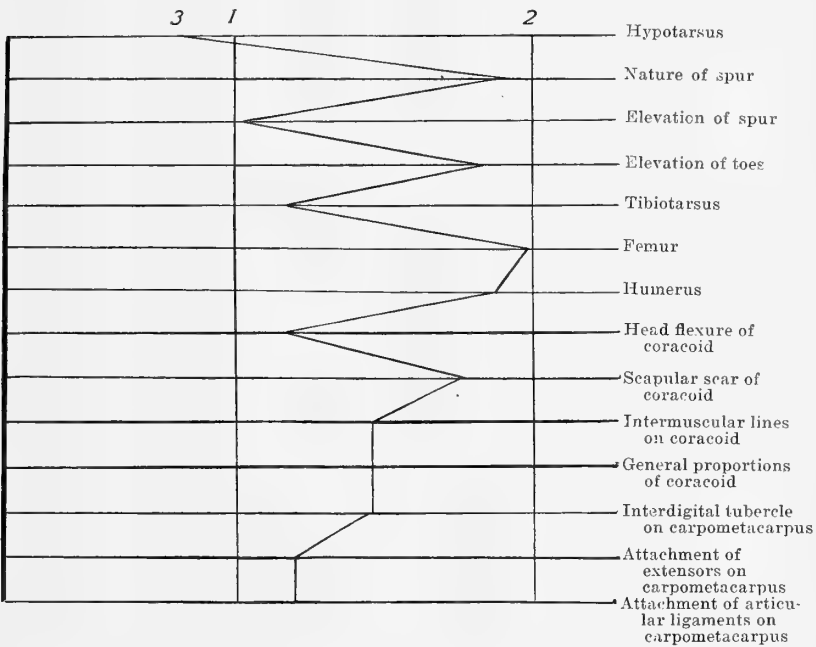


Fig. 2. Curve suggesting the relation of *Parapavo* (3) to the living *Pavo* (1) and *Agriocharis* (2). e.g., In the character of its hypotarsus, *Parapavo* is more remote from *Agriocharis* than is *Pavo*, in the nature of the spur, it is intermediate but approaches closely to *Agriocharis*, in elevation of the spur it is again intermediate but closely approximates *Pavo*, etc. Values approximated only.

are no differences between the birds as known by the tibiotarsus. Adult specimens of both sexes yield the following measurements:

TABLE OF MEASUREMENTS OF THE TIBIOTARSUS						
	P. cristatus		M. ocellatus		P. californicus	
	Male		Male	Female	Male	Female
Total length	197.7 mm.		187.	170.	205.	172.
Least transverse diameter shaft	8.5		9.	9.7	11.5	8.
Transverse diameter through head	10.4		19.3	19.3	23.	18.
Transverse diameter through foot....	18.		17.	17.5	20.	16.8

Femur.—Several points of difference are to be noted on comparing the femur in the living peacock and the ocellated turkey. Proportions are again reversed and *Pavo* is found to be the stouter. The stoutness may however be due to a greater degree of pneumaticity. Several

pneumatic foramina appear upon the anterior face of the trochanter and the whole bone shows a degree of translucence not visible in *Meleagris*. The disposal of the intermuscular lines on both anterior and posterior faces of the femur produces different patterns in the two species, although the difference is hard to define. In its lack of pneumatic foramina and in the pattern of its intermuscular lines the fossil species resembles *M. ocellatus* more than it does *P. cristatus*.

Humerus.—A proper comparison of the humerus in the Recent *Pavo* and *Meleagris* is hardly possible, owing to the fact that this bone in the only available specimen of peacock is either immature or pathological. The posterior limb bears every stamp of complete maturity but the humerus shows the rough, striated surface, the poorly calcified articulations, and the indistinct foramina and muscle scars of a juvenal bird. The only basis of comparison remaining is the general outline, which may not be normal and probably is decidedly abnormal. The indications are that *Pavo* has a longer, straighter, and somewhat weaker humerus than *Meleagris* has. The humerus of *Pavo californicus* is decidedly more like that of *Meleagris* than like the one specimen of *Pavo cristatus* when the adult bone is considered. When, however, a juvenal specimen of the extinct species is taken for comparison, the resemblance lies decidedly with *Pavo*.

Coracoid.—This bone in *Pavo cristatus* is shorter than in the female *Meleagris ocellatus*. The head of the bone is less abruptly bent over, the articulation of the scapula is less perfectly defined, and the intermuscular lines less pronounced. How much of this difference is due to slow maturing of the pectoral arch and limbs it is impossible to state. The only available coracoid of *P. californicus* which is in perfect condition shows a position intermediate with respect to the two Recent species under discussion. The bone as a whole is much larger than in the female *Meleagris*, the scapular scar is like *Meleagris*, the flexure of the head is like *Pavo*, the intermuscular lines show a pattern intermediate between the two.

Carpometacarpus.—In *Pavo cristatus* this composite bone is long and relatively slender as compared with *Meleagris ocellatus*. The osseous tubercle which passes from the fused digits 2 and 3 toward the ulnar side of the metacarpus is less developed and is placed nearer the proximal extremity of the interdigital space. The process to which the tendon of the extensor metacarpi radialis longior is attached is longer but more slender. The attachments of the articular ligaments also differ in detail of pattern.

In general proportions of the carpometacarpus, and in the nature and position of the interdigital tubercle, the fossil species occupies an intermediate position. In other respects this segment shows its closest affinities to lie with *Pavo*.

CONCLUSIONS

It will be seen from this careful scrutiny of all the available material, both Recent and fossil, that the original conclusion referring the Rancho La Brea species to the genus *Pavo* was not without justification. Removal of the species from the genus *Pavo* and its reference to the genus *Meleagris* would be an arbitrary step prompted simply by the fact that *Pavo* is at present foreign to the Americas. Is this a sufficient reason for such step?

If Marsh⁴ be correct in his determination of *Meleagris antiquus*, the genus *Meleagris* is one of long standing in the Americas. This Oligocene species is based on the distal end of the humerus of a "large gallinaceous bird approaching in size the wild turkey and probably of the same group." It was contemporaneous with *Oreodon* in certain lake deposits of Oligocene age east of the Rockies. The specimen was said to agree in the main with *Meleagris gallopavo*, but to lack the broad longitudinal ridge on the inner surface of the distal end opposite the radial condyle, also to lack the abrupt termination of the ulnar condyle at its outer superior border. The specimen was not figured and there is nothing in the brief description which will place the species in *Meleagris* rather than in *Pavo*. The only other meleagrines known from America are *M. celer* Marsh and *M. superba* Cope from the Pleistocene of New Jersey. There is no apparent reason for considering the differentiation of *Pavo* from *Meleagris* as running back to Oligocene time nor for denying the presence of *Pavo* in the New World up until Recent time. Still less is there reason for ignoring the possible intermigration of Old and New World phasianids. The distinction by ornithologists between *Pavo* and *Meleagris* is based largely upon external characters.

Osteologically *Meleagris ocellatus* is almost as near to *Pavo* as it is to *Meleagris gallopavo*. Various authors have commented on the impropriety of using a common generic name for the two American turkeys, Chapman stating his attitude as follows:⁵ "The differences

⁴ Marsh, O. C., Am. Journ. Sci., vol. 2, Aug., 1871.

⁵ Chapman, F. M., Bull. Am. Mus. Nat. Hist., vol. 8, art. 18, pp. 271-290, 1896.

in the form and the distribution of the warty excrescences of the head and neck, and in the character of the erectile appendages of the forehead, the more highly graduated tail and more rounded retrices, the absence of beard in the male and presence of rudimentary spurs in the female are all characters which entitle *ocelletus* to generic distinction, and I would suggest, therefore, that it be placed in a new genus for which I propose the name *Agriocharis*.⁶

The superficial characters of the ocellated turkey are such as to give it the local Spanish name of "Pavo de Yucatan." The ocellated feathers in certain portions of the tail constitute a character comparable to, though not identical with the similar appearance in *Pavo*—a character which is hard to attribute to convergent evolution. This superficial resemblance, combining with those seen in the skeletons, indicates a close relationship between the New and the Old world phasianids. The fossil species from the asphalt is, in the combination of its osteological characters, intermediate between the Yucatan and the oriental birds, which are separated at present by subfamily distinction. It would seem imperative therefore to establish generic distinction for the Pleistocene bird. For this genus the name *Parapavo* is proposed. In a study of the phylogeny of the Phasianidae, a most logical place to search for intermediates between phasianines and meleagrines would be the Pacific Coast of North America. This search has been rewarded, and furthermore Chapman's conclusion that the of a former much wider range finds support in the occurrence at Rancho La Brea of its Pleistocene relative, *Parapavo californicus*.

⁶ The writer is indebted to Dr. C. W. Richmond for a note on the priority of *Agriocharis* over *Eumeleagris*, a name proposed by Dr. Coues.

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Issued January 18, 1916

THE OWL REMAINS FROM RANCHO LA BREA

BY

LOYE HOLMES MILLER



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LOYE HOLMES MILLER

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INTRODUCTION

These nocturnal birds of prey appear, for some reason, much less commonly in the asphalt beds than do those generally distinguished as diurnal hunters, the Accipitres. This difference is notable both in point of numbers and in variety. Whereas the great group of hawks and eagles makes up full fifty per cent of the whole mass of bird material taken from these beds, the owls represent no more than five per cent. Twelve species of accipitrines have thus far been determined from the mass, while many yet remain unidentified. On the other hand, but six species of owls are to be distinguished in the same collection. We thus have a preponderance of ten to one in numbers and of more than two to one in species in favor of the diurnal birds of prey.

At the present time we might expect to find, at most, sixteen accipitrines in the southern California region, while as many as eight species of owls are recorded from the same locality, a ratio of two to one. In point of numbers it would be difficult to make an accurate estimate of the living population, though it would certainly

not seem to be so large a ratio as is shown by the fossil remains. Does the ratio displayed in the collection of remains represent the true faunal relation of these two groups at the time of deposition?

Were we to assume that the proportion of owls to hawks at the present time represents the true condition of affairs at the time the asphalt deposits were forming, it would be necessary to concede that owls were for some reason less positively attracted to the theatre of action at Rancho La Brea than were the hawks and eagles. Does the owl less often feed upon dead or disabled prey? Does it less commonly alight in hunting and therefore escape the asphalt trap?

During several years' acquaintance with the Rancho La Brea region, the present writer has been much interested to watch the Recent outflows of crude oil for the operation of the trap as it is set today. Conditions prevail there at the present time which must approximate somewhat closely, except for magnitude, the conditions in Pleistocene time. In the Recent outpourings of raw asphalt the following species of birds have been noted still in the flesh:

	Individuals
Barn owl, <i>Aluco pratincola</i> (Bonaparte)	3
Night heron, <i>Nycticorax nycticorax</i> (Linnaeus)	2
Green heron, <i>Butorides virescens</i> (Linnaeus)	2
Meadow lark, <i>Sturnella neglecta</i> Audubon	2
Shore bird (indeterminate)	1
Turtle dove, <i>Zenaidura macroura</i> (Linnaeus)	1
Pigeon, <i>Columba livia</i> Domestic	1
Peregrine falcon, <i>Falco peregrinus</i> Tunstall	1
Night hawk, <i>Chordeiles</i> , sp.	1
Linnet, <i>Carpodacus mexicanus</i> (Müller)	1

These observations, so far as they are of value, go to show that owls are among the most common victims of the asphalt and hawks among the least. Certainly it would seem that the region is not unattractive to owls.

Dr. Joseph Grinnell, Director of the California Museum of Vertebrate Zoology, in an informal conversation on the matter expressed an opinion, the recording of which he has kindly permitted. In brief it is this: Owls hunt by sound instead of by sight. The whole specialization of the bird through enlargement of the auditory apparatus to receive the slightest sound and the softening of the plumage to prevent confusion by whirring flight, points to the dependence of the bird upon the slightest noise made by the prey. Hence, unlike the hawk who hunts by

sight, the owl would not be tempted to so great an extent by the asphalt victim. This aspect of the question is probably a very important one, although some evidence may be noted running counter to it. Captive owls are fed quite as readily upon non-living food as are the hawks, even when the food bears no optical resemblance to the natural prey. Owls also will alight upon mouse-baited steel traps set for carnivores; thus we have the suggestion that sound is only one factor in the discovery and selection of the prey and the supposed difference in the carrion habit of the hawks and the owls is reduced materially as a factor in the prime question.

Exposure of fresh asphalt was doubtless in more extensive masses during the Pleistocene than at the present time, else it had been impossible to entangle the large animals whose remains occur in these beds. Such conditions would have increased the proportion of large hawks and eagles in the catch and at the same time perhaps reduced the number of small hawks and especially of owls, since in the larger mass of asphalt, small prey captured during the day when the asphalt was most plastic would have entirely disappeared before nightfall. Under such circumstances the bait would be removed from the trap before the twilight hunting-time of the owls arrived. It is a very notable fact that the hawks and falcons are far outnumbered in the asphalt collections by the much larger eagles. It is so hard to concede a living fauna of such proportions that an effort to find some other explanation is natural. While the number and variety of the eagles was undoubtedly greater during this age of mammals, it seems probable also that the larger size of the asphalt outpours and the consequent rapid disappearance of the smaller raptor bait may have had some influence upon the results and that the conclusions naturally drawn from a study of the fossil remains would better be modified in regard to the proportions of the various elements of the fauna.

RECORD OF SPECIES

ALUCO PRATINCOLA (Bonaparte)

This form is by far the most common of the entire group of Striges in the Rancho La Brea deposits. The remains occur at all depths and embrace all characteristic parts of the skeleton so that very accurate determination of the species is made possible. Careful study of this series of specimens fails to bring to light any variation outside that natural to the species as it lives in the region to-day.

OTUS ASIO (Linnaeus)

There occurs in the collection thus far reviewed a single specimen of the tarsometatarsus of this species. The specimen is perfect in its preservation and when compared with the corresponding bone of the living species of the region, *Otus asio bendirei*, is seen to accord with it in every particular as perfectly as though taken from the same individual. No other remains of the species have yet come to light.

BUBO VIRGINIANUS (Gmelin)

Aside from *Otus*, the genus *Bubo* is the least commonly represented of all the strigine genera recorded from the asphalt. However, among the fifty thousand or more specimens of fossil birds from these beds, there occur a goodly series of the tarsometatarsus as well as the other more characteristic bones of the limbs, thus affording material for a fairly complete study of variation in the Pleistocene phase of this great owl. When the problem was first attacked, with smaller series at hand, it was found that variation was so extensive and so abruptly discontinuous that specific distinction seemed imperative. However, after careful scrutiny of the equally extended series at the Museum of History, Science, and Art at Los Angeles, and thus supplementing the series in the University collections, curves were plotted which showed practically uniform gradients for the grosser dimensions and the ratios of dimensions. The Pleistocene *Bubo* was thus found to be, like the Pleistocene *Haliaëtus*, a form of very wide range of variation. Like *Haliaëtus* also, the series of asphalt specimens includes within its limits two Recent geographic races, a southern smaller and a northern larger race. *Bubo virginianus pacificus* of Southern California grades up to the lower limits of the Pleistocene series, while the larger *B. v. saturatus* is far surpassed by the larger specimens from the asphalt.

The horned owls from Rancho La Brea would present a difficult problem in classification for the systematic ornithologist who readily distinguishes in size as well as in color between the geographic races of *Bubo virginianus*. The fossil species is distinguished from the Recent by a character not held in common, i.e., great variability in a fixed locality. Some students of geographic races have gone so far as to assert that no fossil bird should be assigned to the same species as a Recent form. In the absence of those external characters upon which the ornithologist in large measure relies, and, in view of the

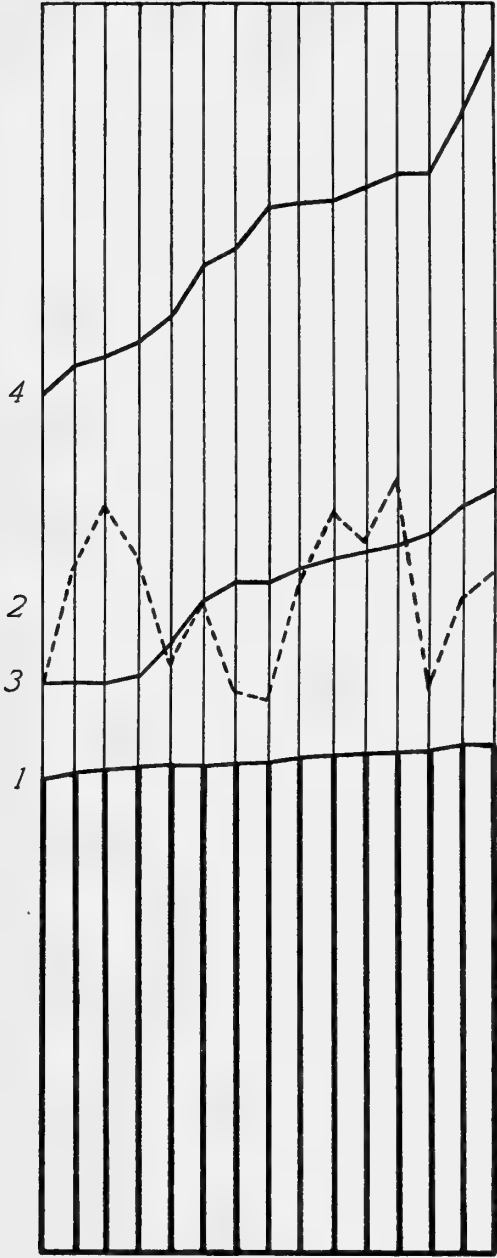


Fig. 1. *Bubo virginianus*. Tarsometatarsus. The line 1 represents total lengths in a series of fifteen individuals, $\times \frac{1}{4}$. Line 2, broken line representing transverse diameters of shaft in the same series in the same order, $\times \frac{1}{16}$. Line 3, transverse diameters of shaft arranged in series, $\times \frac{1}{16}$. Line 4, ratios of diameter over length arranged in series and graphically represented in millimeters as shown in this cut, $\times \frac{100}{1}$.

great variability displayed by the fossil phases of many birds, there would seem to be some measure of propriety in such contention.

ASIO

When the study of the Rancho La Brea birds was first undertaken, one of the most serious obstacles arising was the absence of comparative material representing the Recent birds of America. The genus *Asio* as found in North America today embraces two species, *A. wilsonianus* and *A. flammeus*, both of quite extended range. There are now at hand complete skeletons including the more characteristic limb bones of both species so that a discussion of these parts may be safely undertaken.

Tarsometatarsus.—The osteological characters of the tarsometatarsus appear identical in the two species, the only difference lying in the proportions of the bone. The specimen of *wilsonianus* at hand is a female, that of *flammeus* is of unknown sex. In the owls, as in the diurnal raptors, the female is commonly much larger than the male, with the bones reaching the maximum of length and stoutness. The female *wilsonianus* has a tarsus much shorter than in the one specimen of *flammeus*, yet in all other dimensions the former bone is the larger. Assuming the unsexed *flammeus* to be a male bird, a female would doubtless exceed it in length and thus accentuate the difference between the species. Assuming the specimen to be a female, the difference is still a very positive one. *A. flammeus* seems thus to be a form with a long slender shank as compared with its nearest ally, the short-shanked *A. wilsonianus*.

This difference of the tarsometatarsus is at least not incongruous with the habits of the two birds. *Asio flammeus* is essentially a ground-dwelling species. Its nest is on the ground; its hiding place by day is the long grass of open country; its prey is sought in such places, and after catching its prey the bird alights upon the ground to devour its meal. The other species, in marked contrast, is a bird of the woods. Although its prey may be sought in the open, its hiding place by day is in the dense thickets along watercourses. In such places it builds its nest, the male commonly hiding in the near vicinity. It seems quite possible that the more ambulatory habit of *Asio flammeus* is here seen reflected in the structure of the lower limb.

In the asphalt beds typical tarsometatarsi of both species of *Asio* are found. They seem to have hunted over common ground and to have fallen to a common bait.

Tibiotarsus.—This segment of the limb shows a partial reversal of characters of the two species as displayed by the tarsometatarsus—a reversal which is liable to produce confusion. Corresponding bones from the same individual discussed above show *A. wilsonianus* to have the advantage in length, although the difference is less in proportion than in case of the shank. The greater robustness of *wilsonianus* is apparent and marked. Confusion might however arise between a female of *flammeus* and a male of *wilsonianus*. Such a possibility is illustrated by a tibiotarsus from the same section of the excavation with other remains of both species of *Asio*. It is shorter and yet more slender than the unsexed specimen of *flammeus*, so the question of its identity is a difficulty one to decide. Study of a series of *Asio* material from the asphalt, together with the two Recent specimens, points to the conclusion that the Recent specimen of *A. flammeus* is a female and that the Recent specimen of *A. wilsonianus* is a fully adult bird, though not the maximum in tibial length. A single fossil specimen appears slightly longer and less robust by an almost imperceptible degree.

Humerus.—In sharp distinction to the posterior limb, the humerus of *Asio flammeus* has the short, stout, proportions of a larger bird of strong flight. The bones of the Recent specimens are almost identical in length but the greater robustness in *flammeus* is recognizable at a glance. The transverse and the sagittal diameters at all points give the humerus of *A. flammeus* an appearance of much greater strength of flight than is possessed by the associated *A. wilsonianus*—a conclusion quite in harmony with the fact that the former species occurs unmodified over a large part of the globe and has been taken by deep-water ships as much as eight hundred miles at sea.

ASIO WILSONIANUS (Lesson)

Found fairly commonly in the asphalt, represented by most of parts of the skeleton.

ASIO FLAMMEUS (Pontoppidan)

Found associated with the last-named species and in about equal numbers.

SPEOTYTO CUNICULARIA (Molina)

Next to *Otus* and *Bubo* this little owl is the least common of the group in the beds at Rancho La Brea. It is hard to understand this scarcity of *Speotyto*, except its most exclusively insectivorous habit be the clue. The species is in large degree diurnal, thus missing the smaller rodents to some extent and being less positively attracted to the asphalt trap. It is at present even more an open country bird than is the short-eared owl, *Asio flammeus*. The small size of the species may have permitted the destruction of the remains where more rugged forms have persisted.

The asphalt collections contain representatives of most of the limb bones of *S. cunicularia*.

SUMMARY

There occur in the asphalt beds six species of owls. All are assignable to existing species, though at least one of them, *Bubo virginianus*, displays an unusual degree of variability.

Transmitted August 15, 1915.

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TWO VULTURID RAPTORS FROM THE
PLEISTOCENE OF RANCHO LA BREA

BY

LOYE HOLMES MILLER

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TWO VULTURID RAPTORS FROM THE PLEISTOCENE OF RANCHO LA BREA

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INTRODUCTION

Those decidedly degenerate falconiforms which are classed in the old-world family Vulturidae occupy the same bionomic position within their realm as is filled, in the new world, by the Cathartiformes and the aberrant Polyborinae. An aggressively rapacious habit has, in the vulturids, given place to the more passive manner of the carrion feeder—a change that has its anatomic reflection, to some extent, in the beak but most positively in the foot. This latter member practically ceases its function as offensive armament and loses also in large measure its power as a prehensile organ. The cannon bone of these passive falconiforms may then be very properly expected to show interesting modifications of the raptorial type. Such is certainly the case.

The tarsometatarsus of vulturids is characterized by weak contours throughout. The anterior aspect displays but slight excavation in its proximal region. Passing down the shaft and forming the antero-external contour of the bone is a ridge which, in the active raptors, is sharp and high. In vulturids this ridge is much mollified—a con-

dition reaching its extreme manifestation in *Neophron*. The distal trochleae are weak and come to lie more nearly in the same right and left plane instead of forming that strongly marked arch seen in birds with prehensile feet, such as hawks and owls. The posterior face of the shaft is less deeply excavated for the flexor tendons to the toes. All these are characters indicative of reduction of prehensile power in the foot. They are characters more or less noticeable in all vulturids and they indicate roughly the degree of degeneracy from a more aggressively raptorial type. *Neophron*, which is set off by some writers from other vulturids, as constituting a distinct family, is generally conceded to represent the extreme of this degeneracy and it has the evidence of this degeneracy most indelibly stamped upon the tarsometatarsus. Mainly because of the characters of this bone, the Rancho La Brea species have been placed in new genera of these weak-footed raptors, although in the case of *Neophrontops* other bones of the body less characteristic than the tarsometatarsus correspond with those of the old-world *Neophron*.

NEOPHRONTOPS AMERICANUS, n. gen. and sp.

Type specimen no. 22402, Univ. Calif. Col. Vert. Palae. From the asphalt deposits of Rancho La Brea.

Tarsometatarsus.—The type is a perfect specimen, as well preserved as though freshly macerated from the flesh. The ossification and the distinctness of intermuscular lines indicate an individual of advanced age. Other members of the series have smoother contours. The specimen of *Neophron ginginianus* available for comparison appears from characters of the surface to be a slightly sub-adult bird. In general proportions the two bones are almost identical, the ratio of shaft diameter to length being .072 in *Neophrontops* and .077 in *Neophron*. When viewed from in front, the asphalt specimen is seen to have less pronounced excavation about the papilla of the tibialis anticus. That papilla is thus more prominent and is placed higher on the shaft. The anterior openings of the proximal foramina are closer together. The antero-external contour of the shaft is a little more prominent, as is also the intermuscular line running from the papilla of the tibialis anticus down the front of the shaft. These last two characters may well be due to age in the individual. Distally the shaft widens more gradually into the foot and the trochleae are narrower and weaker. The trochleae are more nearly on the same level.

In the hypotarsal region, *Neophrontops* is seen to have the hypotarsal ridges more prominent, closer together, and without an incipient third ridge between. The hypotarsus is set off more abruptly from



Fig. 1. *Neophrontops americanus*, n. gen. and sp. Natural size. *a*, Tarsometatarsus, anterior aspect. No. 22402. *b*, Tibiotarsus, anterior aspect. No. 22403.

Fig. 2. *Neogyps errans*, n. gen. and sp. Natural size. Tarsometatarsus, anterior aspect. No. 22401.

the shaft below; the bone is more excavated so that parts of the proximal end are appreciably thinner than in *Neophron*. The plantar tendons occupy a deeper groove along the posterior face of the shaft.

Tibiotarsus, cotype no. 22403, Univ. Calif. Col. Vert. Palae.—The tibiotarsus of the asphalt species is almost absolutely identical with that of *Neophron* except that the shaft is slightly more slender and the cnemial crest more prominent. The tunnel under the osseous supratendinal bridge is similarly small and quite in keeping with the weakness of the flexor tendons. The furrow leading to this tunnel is almost obsolete, more so even than in the American *Cathartes*. The intercotylar depression is practically identical with that of *Neophron*. On the inner face of the inner condyle occurs a rugosity marking the attachment of articular ligaments. This rugosity is raised to a tubercle in the active raptors, is less in *Neophron* and is least in *Neophrontops*. Seen from the proximal end the two bones show an identical pattern. From the rear the same holds true.

Humerus.—This bone in the fossil species is practically identical with that of the Recent *Neophron*. Size, curvature, condyles, muscle scars are almost as nearly alike in the two bones as though they had been taken from the same individual. Certainly no tangible difference is noticeable to the writer.

Judging from the remains thus far identified, *Neophrontops americanus* must have been a vulture of about the same size and build as *Neophron ginginianus*. The habits in feeding must also have been fully as far removed from the truly rapacious as in the case of the living bird.

The factor of error in referring the several segments here discussed to the same species is reduced to a minimum by the close resemblance of all the segments respectively to the corresponding parts of the skeleton of *Neophron* and by the repeated occurrence of the various segments together in the same section of the asphalt excavation.

NEOGYPS ERRANS, n. gen. and sp.

Type specimen no. 22401, Univ. Calif. Col. Vert. Palae. From the asphalt beds of Rancho La Brea

Tarsometatarsus.—Slightly smaller than the minimum of *Aquila chrysaëtos*, but general proportions much the same as in that species. The contours much less rugged; papilla of the tibialis anticus more rounded and knob-like and placed higher on the shaft; distal trochleae and outer ridge of the hyptotarsus weaker than in *Aquila*.

Assignment of the genus *Neogyps* to the family Vulturidae is a step which has been taken only after deliberation extending over a

period of years. During this time the problem has been taken up, worked out, and then laid aside many times. During each interval, many specimens of the tarsometatarsus of Pleistocene eagles have been examined, amounting in all to some thousands. In each case the same conclusion has been reached, i.e., that the tarsometatarsus of *Neogyps*, instantly recognizable among many specimens of varied species, presents a markedly vulturid aspect. Only after such mature consideration, strengthened by the occurrence of another vulturid, *Neophrontops*, in the same horizon, is the final and constant conclusion announced. *Neogyps* is either a true vulturid or else an approximation to that group due to convergent modification.

The general impression made by the tarsometatarsus is of a stockily built bird with a general resemblance to *Gypaëtus*, though less in size than *Gypaëtus barbatus*. With the exception of the immediate region of the anterior openings of the proximal foramina, the contours of the bone are less rugged than in *Gypaëtus*; the antero-external angle of the shaft is less sharp; the trochleae are less distinctly set off from the shaft and are less profoundly grooved; the outer hypotarsal ridge is less developed. All these are characters which, in general, distinguish the vulturids from the more predaceous raptorial birds, evidences of degeneracy wherein *Neogyps* seems to have exceeded *Gypaëtus barbatus*.

TABLE OF MEASUREMENTS OF A SERIES OF FOURTEEN SPECIMENS OF THE
TARSOMETATARSUS OF *NEOGYPS ERRANS*

	Type	Average
Length, intercotylar tuberosity to extreme convexity of middle trochlea	88.0 mm.	87.8
Transverse diameter of head	19.6	19.6
Transverse diameter through trochleae	22.6	22.4
Intercotylar tuberosity to center of papilla of tibialis anticus	20.	20.1
Ratio of power arm to resistance arm	22.6%	22.8%

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NOTES ON CAPROMERYX MATERIAL FROM
THE PLEISTOCENE OF RANCHO LA BREA

BY

ASA C. CHANDLER



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NOTES ON CAPROMERYX MATERIAL FROM THE PLEISTOCENE OF RANCHO LA BREA

BY

ASA C. CHANDLER

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INTRODUCTION

Since the description of *Capromeryx minor* Taylor was published in 1911¹ from a number of fragments found in the Rancho La Brea beds, there has been a considerable accumulation of material referable to this species. A study of these specimens brings out a number of interesting points regarding the structure of this animal. Some of these points have a direct bearing on the relationships of *Capromeryx*. With the material now at hand, a very fair estimate of the characters of the animal may be made.

As was pointed out by Taylor, *Capromeryx* is a form of especial interest, since so few antelope-like animals have been obtained in North America, and as yet the relationships of those which have been found are very imperfectly known, so that every addition to our knowledge of any antelope-like form is important.

The material now at hand includes the majority of the limb and foot bones, lower jaws with complete dentition of both milk and permanent sets, fragments of the upper jaw, two pieces of skulls, both including the region of the horn-core, and several vertebrae.

¹ Univ. Calif. Publ., Bull. Dept. Geol., vol. 6, pp. 191-197, 1911.

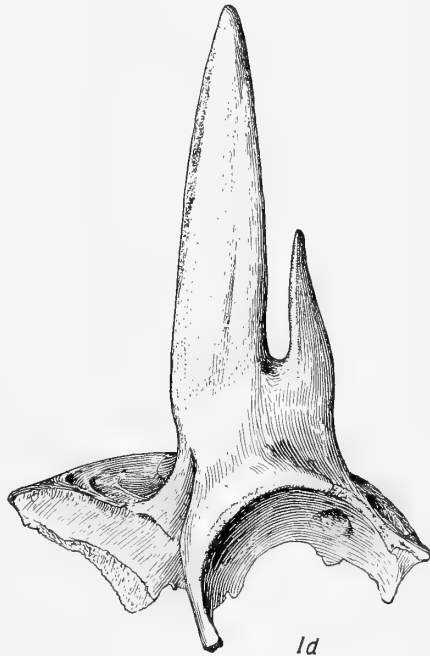
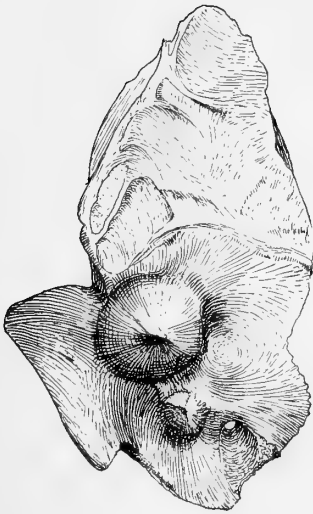
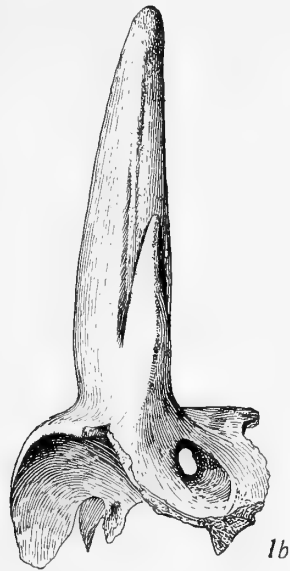
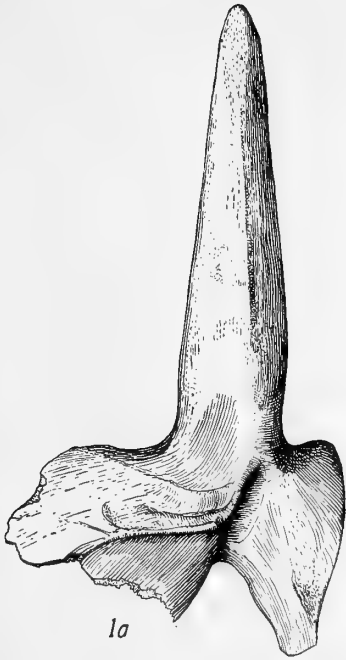
In the preparation of this paper, the author has been very deeply indebted to Professor J. C. Merriam for his kind assistance and co-operation, and to Mr. Frank S. Daggett of the Museum of History, Science and Art in Los Angeles, for his generous loan of material from that museum.

SKULL AND HORN-CORE

Although a considerable quantity of limb bones have been found belonging to this species, there have been discovered up to the present time only a few fragments of skull, two of which include the region of the horn-core and dorsal part of the orbit. Two pieces represent upper jaws with M^1 and M^2 in place in one specimen, and three milk molars in another.

Specimen no. 21445 is a small portion of the dorsal part of the forehead, from the nasal bones to the occipital ridge, and including the dorsal rim of the orbit on the right side, but broken off at the region of the frontal foramen on the left side. This interesting specimen shows the same general contour lines as does *Antilocapra*. It has a prominent orbit, the high arch of the forehead comes between the orbits, instead of behind them as in the deer, and there is a considerable concavity between the anterior borders of the orbits. Whether the nasal bones arched up as prominently as in *Antilocapra* is a matter of conjecture, but the remarkable similarity of the lines of the skull immediately behind the nasal region to the corresponding parts in *Antilocapra* makes it seem highly probable that *Capromeryx* had a similar high-arched nasal region. The frontal foramen has a single opening instead of a double one, and lies in a more marked groove than in *Antilocapra*, in this feature approaching more nearly the deer. There is also, in this species, a shallow pit lying posterior to the frontal foramen, and just external to this a very minute tubercle which, by analogy with *Antilocapra*, represent a rudimentary horn-core of a female animal, although in *Antilocapra* it is considerably more conspicuous.

Specimen no. 49 of the Museum of History, Science and Art of Los Angeles consists of the right side of the parietal and frontal bones with the horn-core and about one-half of the orbit. In the general characters of the skull this specimen agrees perfectly with no. 21445, except that the pit just medial to the horn-core is considerably deeper and more marked.



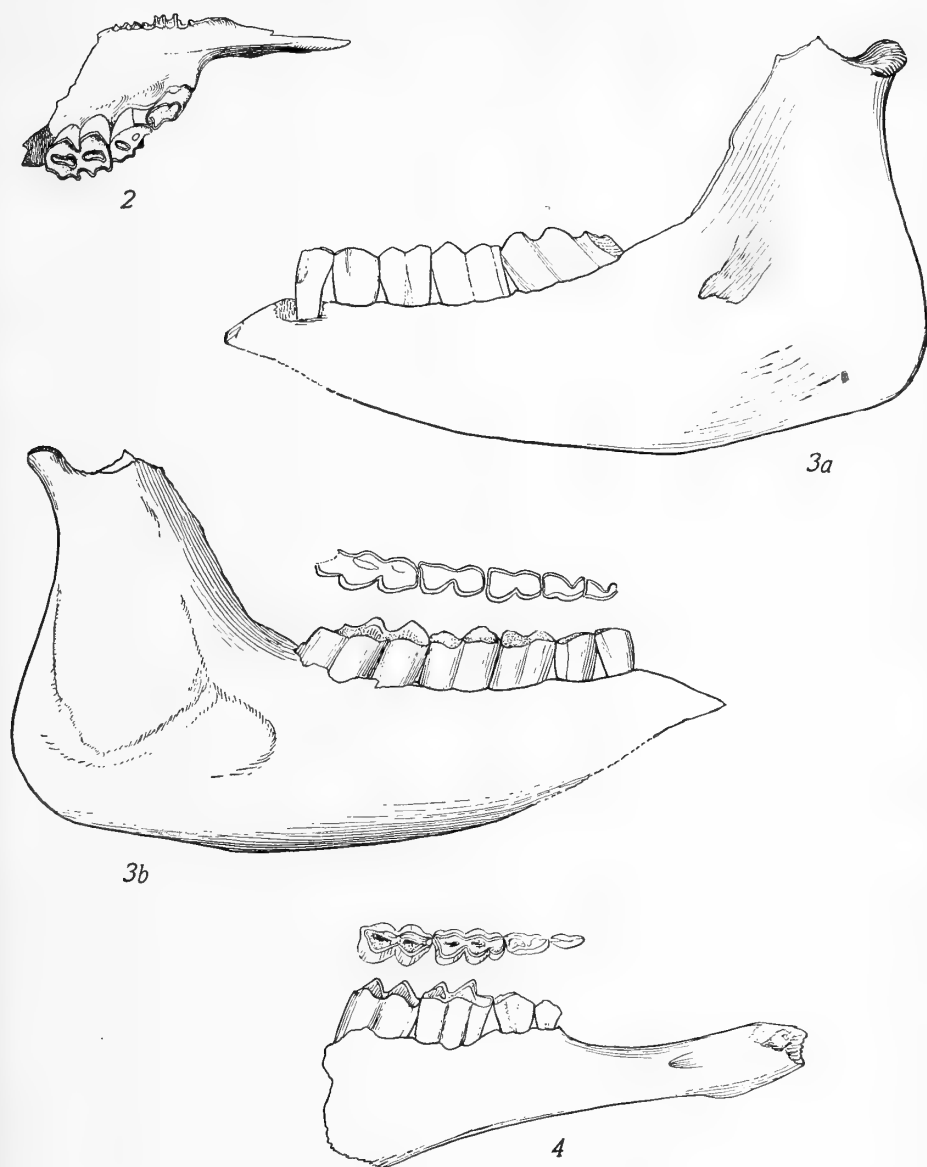
Figs. 1a to 1d. *Capromeryx minor* Taylor. A portion of the cranium with the right horn-core. Specimen no. 49, Museum of History, Science, and Art, Los Angeles, natural size. From the Pleistocene of Rancho La Brea, California.

Fig. 1a, posterior view; fig. 1b, anterior view; fig. 1c, superior view; fig. 1d, lateral view.

The horn-core of this specimen represents one of the most remarkable types yet discovered, and differs widely from that of any other form, either living or extinct. Looking at it in side view it has the appearance of a double horn growing from a single broad base (fig. 1*d*). The larger posterior prong, which reaches to a height of 65 mm. above the dorsal rim of the orbit, is more or less cylindrical, though somewhat flattened on the anterior face, and tapers evenly from the point of separation from the smaller anterior prong. The latter does not have the usual appearance of a fork, but grows out parallel to the larger prong from a common broad base about 15 mm. high, which gives the impression of a growing together of the basal portion of two horns rather than the broad base of a single horn which has two forks. The anterior prong is not only shorter but of much smaller calibre than the posterior prong. It is triangular in cross-section, having a broad flat posterior face, the apex of the triangle pointing anteriorly (fig. 1*b*). From the posterior view the anterior prong does not appear at all (fig. 1*a*). Figure 1*c* shows the appearance of the horn-core looking straight down at it from above, and makes clear the relation of the two prongs to each other. From what sort of a horn-core this very unusual type might have been derived cannot be suggested with any reasonable assurance as yet. Its relation to the horn of *Antilocapra* is also doubtful. While it may represent an entirely independent offshoot from a common ancestor, it may also be in the direct line of descent of *Antilocapra*. In fact, the peculiar sword-like shape of the horn-core of the pronghorn antelope can more easily be imagined to have developed from the type of horn found in *Capromeryx minor* than from any other known kind of horn-core, merely by a further growing together of the apposed faces of the two prongs. The form of the horn sheath, with its long posterior and short anterior prong, might be looked upon as suggesting an ancestral condition in which the horn-core was also forked. There is no other known case in which a simple horn-core possesses a forked sheath.

JAWS AND DENTITION

Specimen no. 20032 is a fragment of the right maxillary bone with M^1 and M^2 in place. These teeth resemble their counterparts in *Antilocapra* very closely, the only difference in form being in the slightly better development of the outer styles. These teeth of *Capromeryx* are almost exactly two-thirds the size of the corresponding ones of *Antilocapra*.



Figs. 2 to 4. *Capromeryx minor* Taylor. Jaws and dentition, natural size, from the Pleistocene of Rancho La Brea, California.

Fig. 2. Left maxillary with milk dentition, from Museum of History, Science, and Art, Los Angeles.

Figs. 3a and 3b. Right ramus of mandible with dentition, no. 20036, natural size.

Fig. 4. Right ramus of mandible with milk premolars and M₁, no. 19977, natural size.

A very interesting specimen, belonging to the Museum of History, Science and Art of Los Angeles, is a portion of the left maxillary bone with the three milk molars in position (fig. 2). Dm^2 is considerably worn, and no lakes are present. Dm^3 is also much worn, but there is still present a fairly large posterior lake and a small anterior one which is almost lost. Dm^4 is almost identical with permanent M^1 in form. The total length of the row of milk teeth is 21 mm. while the premolar series in *Antilocapra* measures 28 mm. The length of Dm^4 is 9 mm., while that of the permanent M^1 is 10 m.

Since 1911, when Taylor's description was written, enough lower jaw material has been accumulated to give an acquaintance with practically all the teeth of the lower jaw of both milk and permanent dentition, as well as with the general proportions of the jaw itself. In general it may be said that the dentition, in both sets, strikingly resembles that of the modern pronghorn, although there are a few significant differences.

Dm_2 , the first cheek-tooth of the lower jaw, is a narrower tooth than the permanent P_2 of *Antilocapra*, and not as well developed, and has a much shallower anterior open valley, though in general they resemble each other.

Dm_3 and permanent P_3 resemble each other in that the anterior valley is open on the inner side in both, but they differ in size, the permanent tooth being shorter than the milk tooth, but broader and heavier. P_3 of *Capromeryx* is very much simpler than the same tooth in *Antilocapra*, the lobe posterior to the open inner valley being unmodified in the former, but furnished with an enclosed lake in the latter.

Dm_4 is a three-lobed tooth, very similar to Dm_4 of *Antilocapra*, but relatively a little larger. Permanent P_4 however, which replaces it, differs very considerably, not only from its own predecessor, but from its counterpart in *Antilocapra* as well. To a striking extent, it resembles permanent P_3 of *Antilocapra*, having the anterior valley wide open on the inner side, and a well-marked outer posterior groove as well as one on the posterior margin of the tooth. The last is not deep, and is therefore noticeable only on very slightly worn teeth.

Permanent M_1 and M_2 are so similar to those of *Antilocapra* that no points of difference in them can be picked out, so far as form is concerned. M_3 , however, is more primitive than M_3 of *Antilocapra* in the inferior development of the fourth lobe or heel. While in the modern species this tooth normally has a very distinct fourth lobe,

in *Capromeryx* this is only suggested by a slight elongation of the third lobe. It is interesting to note that in an abnormal specimen of *Antilocapra americana* (U. C. M. V. Z. no. 8299) the last lobe is missing, the condition being identical with that found in *Capromeryx*. M_3 of the latter is directly intermediate between *Antilocapra* and the older *Merycodus*, since in the latter the third lobe is not only not divided but is considerably smaller than either of the other lobes.

The degree of hypsodonty of both milk and permanent teeth is comparable with that in *Antilocapra*, being far in advance of *Merycodus* in this respect, as has previously been pointed out by Taylor for the milk dentition. As is indicated below, the lower jaw is relatively shorter than that of the pronghorn, and while the lower row of cheek-teeth is longer in *Capromeryx* relative to the length of the jaw, it is shorter relative to the size of the body, which in most measurements averages about two-thirds the size of *Antilocapra*.

The mandible of *Capromeryx minor* differs considerably from *Antilocapra* in its proportions. The depth of the jaw is relatively much greater in *Capromeryx*; the vertical ramus stands more nearly at right angles to the horizontal ramus; the diastema between cheek-teeth and incisors is almost equal to the length of the tooth-row in an *Antilocapra* in which the permanent dentition is all functional but slightly worn, while in a specimen of *Capromeryx* of similar age it is less than two-thirds as great; the anterior dental foramen is much nearer the tip of the symphysis than to P_2 in *Antilocapra*, while in *Capromeryx* it is about half-way between, on account of the shortening of the jaw between the foramen and the cheek-teeth. To sum up, it may be said that the jaw of the diminutive extinct antelope is relatively shorter and heavier than that of its modern relative, and that this shortness of the jaw very probably was correlated with a shorter snout.

VERTEBRAE AND RIBS

Axis.—The axis very much resembles that of *Antilocapra*, but has a deeper and thinner ventral ridge, and a relatively smaller centrum. The transverse processes do not reach as far posteriorly as the ventral tip of the centrum, whereas in *Antilocapra* they reach very considerably beyond. The vertebrarterial canal is relatively very large.

Thoracic vertebrae.—A fragment of what is probably the eighth thoracic vertebra has been found. It has a relatively long centrum and large demifacets for rib articulations.

Lumbar vertebrae.—Several fragments of lumbar vertebrae have been found which are probably referable to this species. No. 21446 is a perfect lumbar vertebra, probably the fifth, which differs from that of *Antilocapra* in the shape of the neural spine, which is considerably wider along its dorsal edge than in the middle of its length, and in the deep incurving of the contour in lateral view on the posterior side of the neural spine. The centrum in this and another similar specimen is of slightly different shape from that in the pronghorn, being relatively broader and not so deep, enclosing a larger neural canal.

Ribs.—No well preserved ribs referable to *Capromeryx* have yet been found, only a few fragments being at hand, from which no definite comparisons may be made.

ARCHES

Scapula.—Several broken pieces of scapulae show that while in general proportions, shape, etc., there was no striking difference between *Capromeryx* and *Antilocapra*, the former was a little more like the latter than like *Ilingoceros*. The anterior edge of the articular surface of the glenoid cavity is well separated from the coracoid process. The lateral prominence of the coracoid process is poorly developed. Viewed from its proximal end, the outer border of the glenoid cavity forms an even curve with the coracoid process as it does in *Antilocapra*, *Ilingoceros* differing from both in this respect. The anterior border of the glenoid cavity is produced into a sharp ventrally projecting point. The scapula of *Capromeryx* is about five-eighths the size of that in *Antilocapra*.

Pelvis.—A few fragments of pelvis show no important points of difference between the existing American antelope and the diminutive extinct species. The acetabulum is relatively slightly smaller in the fossil species.

LIMB BONES

Specimens of a considerable number of the limb bones of this species have been found, and show that, as was suggested by Taylor, it was a form with long, light limbs, comparable with those of the pronghorn.

A few fragments of humeri have been found, but no femur. The humerus is, if anything, slightly more slender than that of *Antilocapra*, and very much the same in structure.

A complete radius and a number of fragments have been found. The length and proportions relative to the rest of the skeleton are not

appreciably different from the condition in the pronghorn. The groove for the ulna on the posterior side is very conspicuous, and the proximal articular surface is not so much expanded as in *Antilocapra*. No ulna has yet been recovered. The tibia is considerably more slender than is that of *Antilocapra*, and is a little more nearly circular in cross-section than is that of the Recent species.

A large number of metapodials have been found, including a number of complete ones, the great majority, however, being from the hind limb. In the anterior metapodials the groove on the anterior face is very slight, in fact almost obsolete, but the posterior groove is both broad and deep, much more conspicuous than in *Antilocapra*. The posterior metapodials were fully described and figured by Taylor.²

A considerable number of well-preserved astragali and calcanei have been found, although other ankle and wrist bones have not certainly been identified.

The new series of astragali show that the specimen upon which Taylor based his description was somewhat worn, and that this caused him to draw some erroneous conclusions. The knob on the inner side of the central dorsal fossa is fully as well developed as in *Antilocapra*, and more so than in *Ilingoceros*. The groove on the dorso-proximal articular surface is more pronounced than in *Ilingoceros*, and this articular surface swings around ventrally farther than in *Ilingoceros*, in both these respects approaching *Antilocapra*. The central dorsal fossa is smaller and deeper than in either of the other genera mentioned. Between the knob described above and the anterior articular surface there is no deep groove as there is in *Antilocapra*, this condition agreeing with that in *Ilingoceros*. A further similarity to the latter is shown in the contour of the distal end, where the trochlea is distinctly rounded and the sides tend to become flattened as in the cervid type. The proximal trochlea is narrower and deeper than in the other genera. The projection on the inner proximo-ventral angle is nearer to that of *Antilocapra*, while the whole distal half of the outer aspect, and the groove into which the calcaneum fits on the ventral side are more suggestive of *Ilingoceros*.

The calcanei, some perfect specimens of which are at hand, tend to corroborate the evidence given by the astragali, that *Capromeryx* is in some respects nearer to *Ilingoceros*, but in most characters approaches more closely to *Antilocapra*. The groove on the inner surface, adjacent to the articulation with the cuboid, is very distinct, and has

² *Op. cit.*

approximately parallel sides. In *Ilingoceros* this groove does not widen distally as much as in *Antilocapra*, and in both the latter forms the groove is but slightly differentiated from the rest of the inner surface. The surface interior to the articulation with the ventral side of the astragalus is narrow and elongated, very different from *Antilocapra*, this condition being due to the very marked sloping off of the prominence bearing the articulation with the ventral side of the astragalus. *Ilingoceros* is intermediate in this respect. The shape of the main articular surface for the astragalus is similar to that of *Antilocapra*, and unlike that of *Ilingoceros*. The articular surface for the cuboid has not quite so much sigmoid curvature as has *Ilingoceros* but has considerably more than *Antilocapra*. The notch in the side of the articulation with the fibula is deeper and sharper than in either of the other genera. There is a well-marked groove just above the articulation with the cuboid which is very shallow in *Ilingoceros* and practically absent in *Antilocapra*.

A number of well-preserved proximal and middle phalanges corroborate the evidence of the other limb bones, that this species was a very light-limbed form. The narrowness from the inner to the outer side of the proximal phalanges as compared with the anteroposterior diameter is striking. In both *Ilingoceros* and *Antilocapra* these dimensions have a ratio of 5 to 6 at the proximal end, while in *Capromeryx* the ratio is 4 to 6. Another characteristic is the great amount of tapering to the point of shortest anteroposterior diameters, the ratio between the narrowest and widest diameters being in *Capromeryx* 1 to 1.76, in *Antilocapra* 1 to 1.60, and in *Ilingoceros* 1 to 1.36. A single minute middle phalanx has the same characteristic compressed appearance. The anterior surface just back of the distal articulating surface comes to a distinct ridge instead of being broadly rounded. This portion of the phalanx sags down so as to give a distinct dip in the anterior contour. In these respects as well as in general form this species is much nearer to *Ilingoceros* than to *Antilocapra*.

The toe bones were described and figured by Taylor³ and as pointed out by him, they are nearer to the form of the toe bones of *Ilingoceros* than to any other forms at hand. They have a distinct "roman-nose" dorsal contour, which is characteristic of antelopes as contrasted with deer. The dorsal convexity, as pointed out by Taylor, is not as marked as in *Antilocapra*.

³ *Op. cit.*

Transmitted May, 1914.

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A STUDY OF THE SKULL AND DENTITION OF
BISON ANTIQUUS LEIDY, WITH SPECIAL
REFERENCE TO MATERIAL FROM
THE PACIFIC COAST

BY

ASA C. CHANDLER

UNIVERSITY OF CALIFORNIA PRESS
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A STUDY OF THE SKULL AND DENTITION OF BISON ANTIQUUS LEIDY, WITH SPECIAL REFERENCE TO MATERIAL FROM THE PACIFIC COAST

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ASA C. CHANDLER

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INTRODUCTION

Few groups of Pleistocene vertebrates have given occasion for such large difference of opinion regarding the status and relation of forms as have the bison. The extremes of views held in regard to the speciation of bison have been held by Brandt¹ and Lilljeborg² on one hand, who regarded all the bison, both living and extinct, as representing a single species, and Lucas³ on the other, the latter recognizing no less than seven species from North America alone. Hay⁴ has recently

¹ Brandt, J. F., Zoogeog. und Palaeont. Beiträge, pp. 101-152 (Verhandl. mineral. Gesells. St. Petersburg, vol. 2, 1865).

² Lilljeborg, 1874.

³ Lucas, F. A., Proc. U. S. Nat. Mus., vol. 21, pp. 755-771, pls. 65-82, 1899.

⁴ Hay, O. P., Proc. U. S. Nat. Mus., vol. 46, pp. 161-200, pls. 8-19, 1913.

added a species to those described by Lucas, though apparently not recognizing some of the described species.

This wide difference of opinion may be attributed largely to the diverse beliefs regarding the extent of individual variation and of sexual dimorphism in the various members of the groups, this in turn being due to the incompleteness and more or less fragmentary nature of the material which could be referred with certainty to any particular extinct species.

In the collections of the Department of Palaeontology of the University of California there is a comparatively large series of skulls of *Bison antiquus* from a number of localities in the Pacific Coast region of North America, all, so far as known, of Pleistocene age, and representing, without any reasonable doubt, a single, well-defined form. It is hoped that descriptions and comparative measurements of some of these specimens will throw light on the problem of relationships of the species.

INDIVIDUAL AND SEXUAL VARIATION IN EXISTING SPECIES

Due to the dissociation of parts, and the fragmentary nature of most of the specimens which have hitherto been found the classification of extinct bison has been based largely on the skull and horn-cores, which afford very good comparative characters, but to what extent they represent individual, sexual, or specific distinctions, has been disputed.

Before advancing evidence furnished by the fossil specimens, it seems advantageous to summarize our knowledge of the variation in existing species.

BISON BISON (Linnaeus)

As shown by Dr. J. A. Allen⁵ in his memoir on the American bison, the range of individual variation in the skull of *B. bison* is considerable, much greater than that usually found within a single species, such variation affecting the amount of convexity of the skull, shape of horn-cores, size, relative measurements, etc.

The size in adult male specimens, according to measurements given by J. A. Allen, has a variation of about 20 per cent, the relative measurements being subject to a less degree of variation. The range

⁵ Allen, J. A., Mem. Harv. Mus. Comp. Zool., vol. 4, no. 10, 1876, pp. 1-246, 12 pls., 1 map.

of variation in length of horn-cores, considering only those specimens which are estimated to be ten years of age or older, numbering twelve, is about the same as that of the skull, 20 per cent. The basal circumference of the horn cores is from 10 per cent to 45 per cent greater than the length along the upper curvature. The size of horn-cores seems to vary much more in young animals, sometimes attaining the full growth at an age of four to six years, at other times being far below average size at this age. The variation in amount of curvature of the horns is unexpectedly great, but the general direction of curvature is remarkably constant.

Looking now at the sexual variation displayed by *B. bison*, and referring again to the excellent table of measurements given by Dr. Allen,⁶ we find that the variations within the female sex are very similar to those of the male, but that the average for all measurements is considerably less, and that in some measurements the range of variation in male and female does not overlap. It should be borne in mind, however, that the difference between the sexes is emphasized by the fact that all of Allen's female specimens were under ten years of age. Comparing the average of the measurements of all the males with the average of all the females, we find the latter differing from the former as follows: size of skull, 22 per cent less, with no overlap of measurements; length of horn cores, 23 per cent less; basal circumference of horn cores, 40 per cent less, with no overlap; circumference of horn cores relative to their length along upper curvature, 110 to 145 per cent in males, 81 to 105 per cent in females. No difference can be found between the sexes in the direction of curvature of the horns, the range of variation being about the same in both.

From this it is evident that in *B. bison* the female differs from the male in having a skull about 20 per cent smaller, and in possessing more slender horn-cores. This statement is corroborated by the observation of Rhoads⁷ on the herd of bison belonging to the Philadelphia Zoological Society, containing six females and fourteen males. He points out that the chief sexual difference is in the smaller basal caliber of the horns of the females, the variation in curvature and angle of growth not being greater than that found within a single sex, while their length, due to the relatively longer sheaths, is greater with respect to the size of the body in the females, the cores, however, averaging shorter, and being more distinctly cylindrical throughout.

⁶ Op. cit.

⁷ Rhoads, S. N., Proc. Acad. Nat. Sci. Phila., vol. 49, pp. 483-501, pl. 12, 1897.

BISON BONASUS

Comparing *B. bison* with the European *B. bonasus*, we are struck by the fact that while the two are in many respects very different from each other, and clearly constitute distinct species, the differences in the skull and horn-cores are unexpectedly slight, and while the average *B. bonasus* has a more massive skull with longer horn-cores than *B. bison*, extremes of the two species overlap each other in all respects. So far as can be ascertained from measurements given by Allen⁸ and Meyer,⁹ *B. bonasus* is subject to approximately the same amount of sexual and individual variation as is *B. bison*.

GENERAL ACCOUNT OF BISON ANTIQUUS

HISTORICAL

Bison antiquus was first described by Leidy¹⁰ from a fragment of a horn-core found at Big Bone Lick, Kentucky.

J. A. Allen, in his monograph on American bison,¹¹ included with it a number of specimens which have since been referred to other species. In 1897 Rhoads¹² described *B. californicus* from a cranium which had previously been referred to *B. antiquus* and which was put back in that species by Lucas¹³ in 1899. Lucas also describes an imperfect lower jaw from Alameda County, California, and Hay¹⁴ in 1912 described a fairly well preserved cranium which is in Earlham College, Indiana. So far as I am aware these are the only specimens which have been so far described as belonging to this species.

DESCRIPTION OF NEW MATERIAL

As intimated above, there has hitherto been no adequate basis for determination of the amount of individual and sexual variation, not only in this species, but in any extinct American species of bison. The abundant material, chiefly from the asphalt beds of Rancho La Brea, which is in the collection of the University of California, affords

⁸ Op. cit.

⁹ Meyer, H. von, Über fossile Reste von Ochsen, Nova. Acta. Phys. Med. Acad. Leop. Carol. Nat. Cur., vol. 13, pp. 101-169, pls. 8-12, 1835.

¹⁰ Leidy, Proc. Acad. Nat. Sci. Phila., 1852, p. 117.

¹¹ Op. cit.

¹² Op. cit.

¹³ Op. cit.

¹⁴ Hay, O. P. Geol. Surv. Indiana, vol. 35, p. 650, 1912.

an excellent opportunity for such a determination in *Bison antiquus*, at least. There are thirteen more or less complete crania of various ages, four of which have the horn-cores practically perfect, four have the entire skull perfect or almost so, and five have the dentition almost complete. In addition to this there are numerous fragments, and a very large series of rami, in fact parts of sixteen different animals.

Following is a general description of the specimens at hand, by numbers:

19478. The forehead, with complete horn-cores, of an old male individual. Pleistocene of the John Day region, Oregon. Figs. 1a and 1b.
21154. A complete cranium of an adult male, with one horn-core. Rancho La Brea. Figs. 3a and 3b.
21153. A complete cranium of a young adult male with both horn-cores. Rancho La Brea. Figs. 4a and 4b.
21152. A skull of a young adult, complete with the exception of the outer part of both horn-cores. Inner pillar of M¹ connected, those of M² and M³ unworn. Rancho La Brea. Figs. 7 and 9.
21151. A complete cranium of an adult, with both horn-cores. Rancho La Brea. Figs. 2a and 2b.
21184. A complete skull of an adult, on mounted specimen in University of California. Rancho La Brea.
21182. An imperfect cranium of a young adult, with both horn-cores broken. Rancho La Brea.
21183. A complete skull with the exception of a few teeth, of middle-aged animal. Inner pillars of M¹ and M² connected, that of M³ only slightly worn. Rancho La Brea.
21186. An incomplete cranium of a young adult, with one horn-core missing. Rancho La Brea.
21187. Portion of skull, with one horn-core, and a few teeth. Rancho La Brea.
21188. Nearly complete skull of a calf, but both horn-cores broken. Milk molars present, permanent M¹ just coming in. Rancho La Brea.
21185. Skull of old animal, complete with exception of one horn-core. Inner pillars of all molars well worn. Rancho La Brea.
21190. Incomplete cranium of young adult, with both horn-cores broken. Rancho La Brea.
21443. Left half of upper jaw, with four teeth. Old, inner pillars of all molars well worn. Rancho La Brea. Fig. 10.
21444. Premaxilla and front part of maxilla of rather young animal. Inner pillar of M¹ slightly worn. Rancho La Brea.
21433. Imperfect ramus, old. Only molars present. Rancho La Brea.
21432. Imperfect ramus, old. All teeth present. Rancho La Brea.
21432. Imperfect ramus, old. All teeth present. Rancho La Brea.
21434. Ramus, old, complete except for M³ and P⁴. Rancho La Brea.
21442. Complete ramus, middle-aged. Rancho La Brea.
21445. Incomplete ramus, middle-aged. Only molars present. Rancho La Brea.
21184. Restored ramus, middle-aged, all teeth present. Rancho La Brea.
21189. Complete lower jaw, with both rami, only P² absent. Middle-aged. Rancho La Brea. Fig. 11.

21440. Complete ramus, all teeth present. Middle-aged. Rancho La Brea.
21181. Complete ramus, young adult. Rancho La Brea.
21441. Complete ramus, Dm^2 and Dm^3 still in, but nearly pushed out. Rancho La Brea. Figs. 12a and 12b.
21438. Incomplete ramus, P^2 and P^3 unworn. Rancho La Brea.
21439. Incomplete ramus. Dm^2 still in place. Rancho La Brea.
21435. Incomplete ramus, M^2 unworn, M^3 not yet appeared. Rancho La Brea.
21180. Complete ramus. Milk dentition complete. Rancho La Brea.
21437. Front part of ramus. Milk dentition complete, only M^1 in place. Rancho La Brea.
21436. Complete ramus, Dm^3 unworn. Rancho La Brea.

CRANIUM

An examination of the measurements of all the specimens of *B. antiquus* considered in Table I, except 21183 and 21188, which are excluded on account of their youth, shows that in none of the measurements of the cranium is there more than 20 per cent variation, and in some of the measurements considerably less than that. It is strange that the measurements of the facial region are throughout far more constant than those of the cranial region. For instance, in the basinasal length there is a variation of over 16 per cent, and in the distance from the foramen magnum to the rear of the hard palate, about 20 per cent, while in none of the facial measurements does the variation exceed 10 per cent. The same tendency for greater variation in the cranial portion of the skull is shown by the table of measurements given by Allen for *B. bison*, but is not as marked.

An examination of the measurements shows at once that the specimens fall into two natural groups, one with small, slender, horn-cores, the other with large, robust horn-cores. By analogy with the existing species, we may safely assume that the former are females, and the latter males. While there may be slightly smaller average measurements of the skull proper in the females than in the males, the difference is inappreciable. In the horn-cores, however, the difference is striking. From tip to tip of the horn-cores there is a variation of about 10 per cent in the males, and 12 per cent in the females, but there is a difference of over 20 per cent in the average measurements of the two sexes, with no overlap. Looking now at the measurements of single horn-cores along the upper curvature, we find a still greater difference, in fact, over 25 per cent, since the difference in extent of horns is due entirely to the length of the horn-cores, the width of the forehead being fairly similar in both sexes. In circumference at the base of the horn-

Lower border of
 rear of nasal
 Occipital crest
 along median
 Rear of condyle
 Line joining rostral
 premaxillae .
 Lower border of
 rear of hard
 Rear of hard
 maxillae
 Width of forelimb
 horn-cores ...
 Width at narrowest
 horn-cores at
 Width between
 base of crowns
 Width between
 noses of P² ..
 Antero-posterior
 Length of nasal
 Width of nasal
 line
 Same as last measurement

Tip to tip of hind
 Length of hind
 curvature
 Circumference
 Circumference
 Diameter of hind
 Dorso-ventral

Antero-posterior

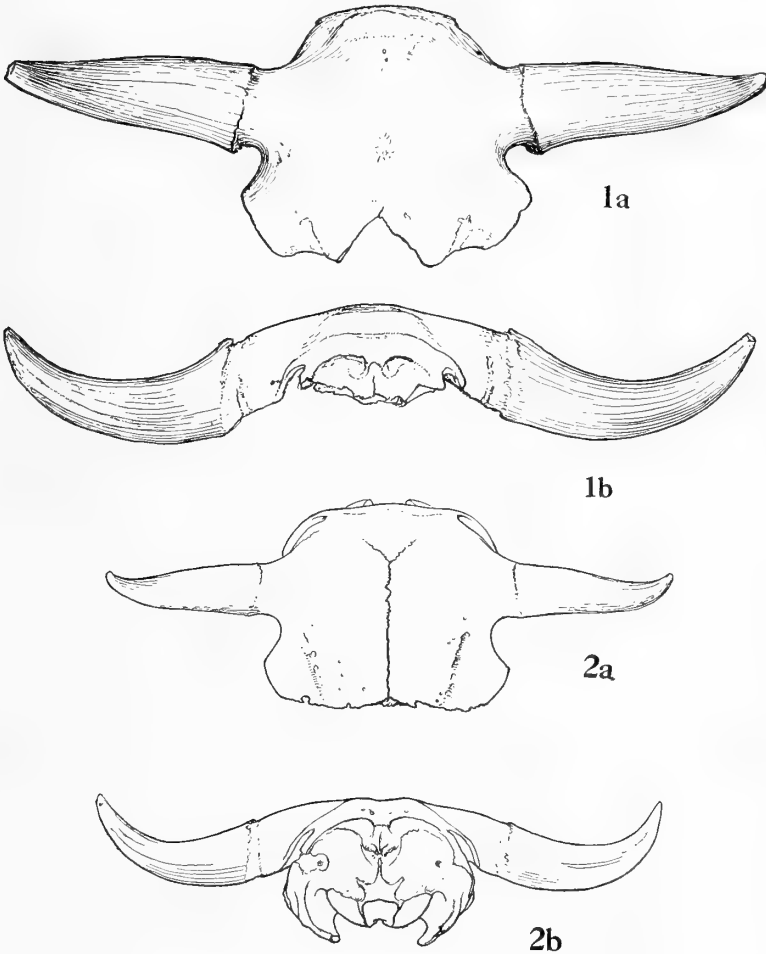
* Approach

TABLE I
MEASUREMENTS OF SKULL

	Bison bison U. O. M. V. Z. 5597	Bison bison U. O. M. V. Z. 5596	Bison bison M. O. Z. 1102 after J. A. Allen	Bison bison M. O. Z. 1101 after J. A. Allen	Bison bonasus U. S. N. M. 11514 after J. A. Allen	Bison bonasus M. O. Z. 1790 after J. A. Allen	19478 John Day	21154	21153	21152	21151	21184	21182	21183	21186	21187	21188	21185	21190	21443	"B. californicus" after Hay	Earlham College specimen	Type from Big Bone Lick, Ken- tucky
Lower border of foramen magnum to rear of nasals (basinasal length)	270 mm.	270	.....	.....	.....	.....	255	285	290	276	270	285	260	257	263	260	220	290	273	.....	.....	292	.....
Occipital crest to fronto-nasal suture along median line	240	245	214	210	265	208	265	272	276	240	252	263	242	220	244	245	210	226	243	.....	.....	.....	.....
Rear of condyles to tip of premaxillae	.....	.....	.....	.....	.....	.....	.....	.....	.....	610	.....	632	.....	564	.....	.....	.....	582*	.....	.....	.....	.....	.....
Line joining rear of orbits to tip of premaxillae	.....	.....	.....	.....	.....	.....	.....	.....	.....	421	.....	424	.....	398	.....	.....	.....	440*	.....	.....	.....	.....	.....
Lower border of foramen magnum to rear of hard palate	200	205	.....	.....	.....	.....	.....	.....	.....	234	.....	247	..	200	..	..	156	214	202	.....	.....	.....	.....
Rear of hard palate to tip of premaxillae	.....	.....	.....	.....	.....	.....	.....	.....	.....	336	.....	348	.....	325	.....	.....	.....	325	.....	334	.....	.....	.....
Width of forehead between bases of horn-cores	325	330	255	214	270	205	347	417	397	406	320	340	...	305	... ..	275	195	290	297	.....	392	400	...
Width at narrowest point between horn-cores and eye-sockets	272	270	240	210	267	206	303	309	292	304	270	290	253	265	.....	..	187	256	271	.....	336	....	..
Width between outer sides of M ³ at base of crown	140	.....	.....	.....	.....	.....	.....	.....	.....	160	.....	153	.....	164	.....	...	115 Dm ³	157	169	...	...	...	.....
Width between anterior inner corners of P ²	48x2 =96	.....	.....	.....	.....	.....	.....	.....	.....	93	.....	105	.....	93	.....	...	73 Dm ³	112	.....	.....	.....	.....	.....
Antero-posterior diameter of orbits	70	75	.....	.....	.....	.....	77	70*	70*	85	69	75	73	81	65*	73*	64	72	93	.....	.....	...	.....
Length of nasal bones	.....	222	.....	.....	.....	.....	.....	.....	.....	208	.....	222	.....	220	..	...	..	227	.....	.....	.....	.....	.....
Width of nasal bones in straight line	.....	100	.....	.....	.....	.....	.....	.....	.....	113	.....	102	.....	100	.....	..	.....	115	100	..	...	.....	.....
Same as last measurement with curvature	.....	130	.....	.....	.....	.....	.....	.....	.....	120	.....	120	..	110	.....	.....	.....	135	.....	.....	.....	.....	.....
Tip to tip of horn-cores	640	.....	515	468	560	395	975*	413x2 =826	817	.....	712	735	.....	325x2 =650	..	.....	.....	330x2 =660	...	...	912	880	..
Length of horn-cores along upper curvature	200	.....	146	132	.....	.....	344	275	275	.....	224	224	.....	180	190*	228	.....	235	.....	.....	285	290	..
Circumference of horn-cores at base	230	270*	200	163	200	178	342	310	300	306	219	224	206	198	205	220	140	212	220	..	360	...	364
Circumference of neck of horn-cores	220	250	.....	.....	.....	..	315	295	288	295	228	235	223	208	220	240	138	240	..	.....	.....	.....	.....
Diameter of horn-cores— Dorso-ventral	65	.....	.....	.....	.....	.....	102	102	100	...	65	70	61	63	65	70	42	68	72	..	115†	103†	102*
Antero-posterior	70	.....	..	..	..	.....	105	104	92	96	68	65	65	60	64	68	43	67	71	.....	110†	90†	122*

* Approximate.

cores there is a 33 per cent difference between the two sexes, resulting, of course, in the females having considerably more slender horns. The measurements also show that the neck of the horn-cores, *i.e.*, the por-

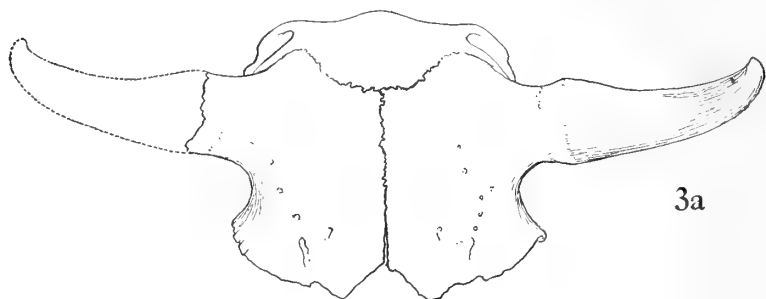


Figs. 1a and 1b. *Bison antiquus* Leidy, ♂. Cranium and horn-cores. No. 19478, $\times \frac{1}{8}$, John Day region, Oregon. Fig. 1a, dorsal view, perpendicular to forehead; fig. 1b posterior view, at right angles to dorsal view.

Figs. 2a and 2b. *Bison antiquus*, Leidy, ♀. Cranium and horn-cores. No. 21151, $\times \frac{1}{8}$, Rancho La Brea beds. Fig. 2a, dorsal view; fig. 2b, posterior view.

tion between the forehead and the rugose horn-covered portion, is of smaller caliber than the base of the horn-core itself in the males, but is greater in females.

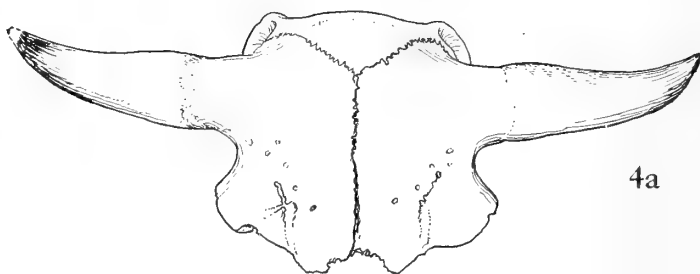
Reference to figures 1a, 2a, 2b, 3a, 3b, 4a, and 4b make it evident that the variation in the horn-cores of *B. antiquus* as regards their curvature, general form, and relations to the skull are very slight. Comparison of figures of the old male from the John Day region (figs.



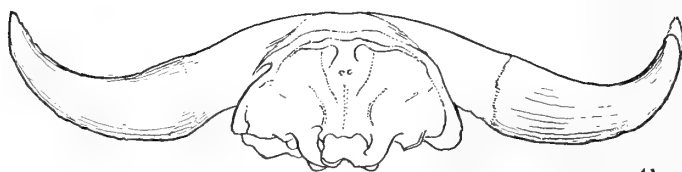
3a



3b



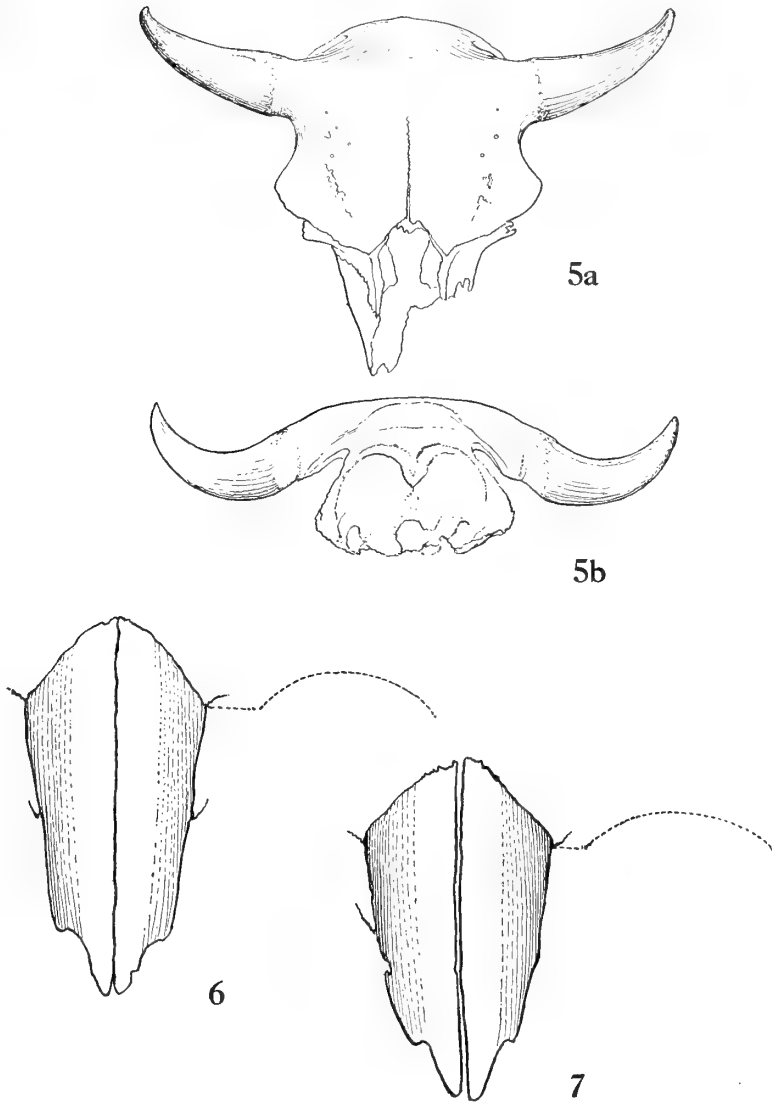
4a



4b

Figs. 3a and 3b. *Bison antiquus* Leidy, ♂. Cranium and left horn-core. No. 21154, $\times \frac{1}{8}$, Rancho La Brea beds. Fig. 3a, dorsal view; fig. 3b, posterior view.

Figs. 4a and 4b. *Bison antiquus* Leidy, ♂. Cranium and horn-cores. No. 21153, $\times \frac{1}{8}$, Rancho La Brea beds. Fig. 4a, dorsal view; fig. 4b, posterior view.



Figs. 5a and 5b. *Bison bison* (Linnaeus), ♂. Cranium and horn-cores. U. C. M. V. Z. No. 5597, $\times \frac{1}{8}$, Great Plains region. Fig. 5a, dorsal view; fig. 5b, posterior view.

Fig. 6. *Bison bison* (Linnaeus). Nasal bones. U. C. M. V. Z. No. 5596, $\times \frac{1}{4}$, Great Plains region.

Fig. 7. *Bison antiquus* Leidy. Nasal bones. No. 21152, Rancho La Brea beds.

1a and 1b) shows that the horn-cores are almost identical with those of two large males from Rancho la Brea, shown in figures 3a and 3b, and 4a and 4b, and also with those of the male from the Pilarcitos Valley, California (figured by Rhoads, pl. 12, fig. 2), and the male in Earlham College (figured by Hay, figs. 2 and 3). Viewing figures 2a and 2b, representing a female from Rancho la Brea, it is evident that aside from the smaller size and relatively somewhat more slender form, there is no appreciable difference in the form of the horn-cores. One of the most characteristic and most readily recognizable characters of the species, as has previously been pointed out by Lucas and Hay, is the angle which the basal portion of the horn-cores makes with the longitudinal axis of the skull. In *Bison bison*, and in all other American species so far described, the horn-cores make a more or less obtuse angle with the median line of the facial portion of the skull (see fig 5a), while in *B. antiquus* they are inserted almost at right angles (figs. 1a, 2a, 3a, and 4a). In *B. bison* the angle bounded on one side by a line from a point at about one-half the distance from base to tip of a horn core along the middle line of the core to the median line of the skull, and on the other side by the longitudinal axis of the skull, varies from 110° to 125° , usually being approximately 120° . In *B. antiquus*, on the other hand, the angle never exceeds 100° , and is frequently an almost perfect right angle. The widest angle made with the skull in any specimen of *B. antiquus* so far described is that of a very young animal, little over half grown, from Rancho la Brea, (21188). In this specimen the angle is about 100° .

Considerable variation exists in the amount of convexity of the forehead, as can be seen by reference to figures 1b, 2b and 4b. This convexity seems to increase somewhat with age, though there is a great deal of variation which is purely of an individual nature.

The amount of variation in the size of the lower jaw is remarkably slight, there being only about 5 per cent difference in length from tip to angle in the extremes of five adult specimens, as shown by Table III. The measurements vary to such an extent with age that it is impossible to distinguish males from females, although, judging by analogy with the modern species, there is probably a slight sexual difference in size.

Comparison of the measurements of the skull and horn-cores shows that *B. antiquus* differs from both the existing species in the relative breadth of the skull. The length, as shown by several different measurements, is approximately the same for all three species, while

the breadth in *B. antiquus* in both sexes is one and a third times that in the corresponding sex of the modern species. There is no noticeable difference in size of the orbits. The nasal bones of *B. antiquus* differ from those of *B. bison* in being relatively shorter and broader, and less arched, tapering more gradually to the tip; so that the notch near the distal end is not so conspicuous. These differences are well brought out by a comparison of figures 6 and 7, and of the measurements in Table I.

The horn-cores are longer and relatively more slender in *B. antiquus* than in *B. bison*, the length of the horn-cores in the females of the former about equalling that of the males of the latter, the basal circumference, however, being much greater in the males of *B. bison* than in the females of *B. antiquus*, but not as great as in the males of the latter. As previously stated, the angle of growth of the horn-cores is considerably different in *B. antiquus* from that in other American species, or in *B. bonasus*, but the curvature is much the same, there being a sagging below the level of the forehead, then an even upward curvature, and a more or less pronounced reflexion of the tips. (Compare figs. 5a and 5b, with figs. 1-4.) In *B. bonasus* the horn-cores seem to be relatively even smaller than in *B. bison*, but the difference in skull and horn-cores between *B. antiquus* and either of the modern species is greater in every respect than that between the two existing species.

DENTITION

The dentition is known by teeth in many stages of wear, that of the lower jaw being especially well represented. The teeth of bison are of little value from a systematic point of view, the individual variation within a species so far overbalancing any average specific difference that may exist that it is difficult to find any constant, reliable specific difference except in size. Hay¹⁵ has shown that the amount of complication of the enamel walls of the lakes of the molars shows a tendency to vary specifically, *B. latifrons* having a very simple pattern, and *B. regius* relatively a very complicated one. Hay states that in several Recent specimens of *B. bison* he finds no inflexion of the enamel on the sides of the lakes of the upper molars, and this statement is borne out by my own observations. Allen¹⁶ figures a specimen of *B.*

¹⁵ *Op. cit.*

¹⁶ *Op. cit.*

bison from Big Bone Lick in which the pattern is complicated as in Hay's figure of *B. regius*. It seems possible that Allen's specimen was in reality *B. antiquus*, since the latter has been found in the same locality, and, as will presently be shown, has more complications of the enamel than have Recent specimens of *B. bison*.

TABLE II
MEASUREMENTS OF TEETH OF UPPER JAW

	21185	21443	21183	21184	21444	21187	21152	21188	U. B. bison, C. M. V. Z. 5597
Length of upper series of cheek-teeth	169 mm.	172	158	172	.....	.....	161	Milk series	144
Length of premolar series	65	68	60	67	70	.....	66	0	58
Length of molar series	100	107	100	107	.....	.....	104	Milk 78	89
P ² Length	20*	.....	21	20	25	.....	22	.....	.....
P ² Width	16	.....	15	?	17	.....	17	.....	.....
P ³ Length	20	.....	19*	22	25	22	21	.....	.....
P ³ Width	23	.....	17	?	21	22	25	.....	.....
P ⁴ Length	19	21	19	21	23	20	24	.....	19
P ⁴ Width	26	28	25	?	25	26	21	.....	21
M ¹ Length	30	29	28	26	32	27	33	Milk 26	26
M ¹ Width	31	30	28	?	25	29	27	19	24
M ² Length	34.5	37	34	35	.....	.....	36	Milk 30	32
M ² Width	33.5	31	30	?	.....	.....	26	20	23
M ³ Length	36	39	36	36	.....	.....	34	Milk 33	30
M ³ Width	32	29	33	?	.....	.....	26	21	22

* Approximate.

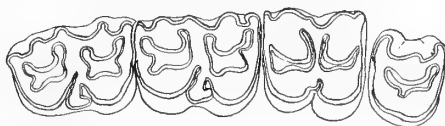
Measurements of upper teeth of several specimens are given in Table II, the length being measured on the grinding surface, the width at the base of the exposed portion of the crown. The length and width of the individual teeth, as well as the length of the tooth series as a whole, varies considerably with wear. The length of the tooth decreases very considerably, while the width remains more nearly the same, increasing slightly for a while, then decreasing toward the roots. Comparison with measurements of the teeth of *B. bison* (U. C. M. V. Z. 5597) which exhibit approximately the same degree of wear as 21185, shows that the upper teeth of *B. antiquus* are considerably larger. The structure of the upper premolars does not differ in any



8



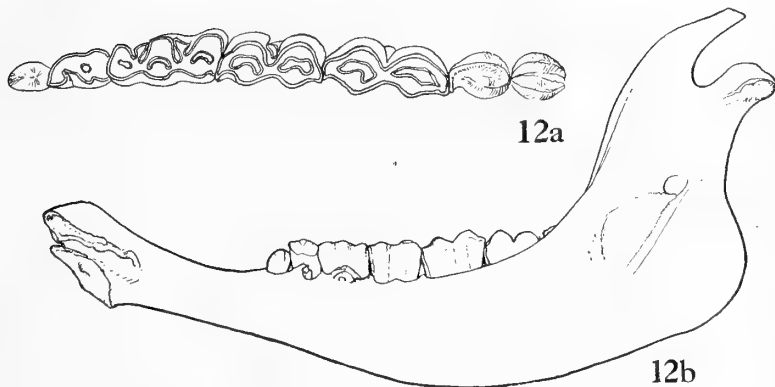
9



10



11



12a

12b

Figs. 8-12. *Bison antiquus* Leidy. Fig. 8, teeth of right upper jaw, P² to M¹ inclusive. No. 21444, $\times \frac{1}{2}$, Rancho La Brea. Fig. 9, teeth of right upper jaw, P³ to M³ inclusive. No. 21152, $\times \frac{1}{2}$, Rancho La Brea beds. Fig. 10. Teeth of right upper jaw, P⁴ to M³ inclusive. No. 21443, $\times \frac{1}{2}$, Rancho La Brea beds. Fig. 11. Teeth of left lower jaw. No. 21189 $\times \frac{1}{2}$, Rancho La Brea beds. Fig. 12a, teeth of right lower jaw. No. 21441, $\times \frac{1}{2}$, Rancho La Brea beds. Fig. 12b. Inner view of right lower jaw. No. 21441, $\times \frac{1}{4}$, Rancho La Brea beds.

important details from that of *B. bison*, except that the posterior inner tubercules of all of them are better developed, in slightly worn teeth, (e.g., 21152) forming a minute lake posterior to the main one. See figs. 8, 9 and 10.

M¹ when once worn flat is almost square with the lakes very narrow and V-shaped, in well-worn teeth the anterior horn of the posterior lake and the posterior horn of the anterior lake reaching relatively far toward the outside (fig. 10).

The sides of the lakes are very slightly indented on 21152 and 21444 (see figs. 8 and 9), while in 21183 there is an invaginating lobe on the anterior side of the posterior lake as in Allen's pl. 10, fig. 7, ascribed to a fossil *B. bison*. M² has wider lakes than M¹, with a more or less well developed invagination of the enamel on the posterior side of the posterior lake compare 21152 (fig. 9) and 21443 (fig. 10), the latter also having an invagination on the anterior side of the anterior lake while on more worn teeth (21183 and 21185) there is no such invagination to be seen. Upper milk molars 2 and 3 are present in 21188, and but slightly worn. They resemble permanent molars, except for their smaller size, and the relatively greater size and different form of the small inner lobe between the protocone and hypocone. In Dm³ of 21188 this lobe is long and tongue-like, about 8 mm. long, with its widest anteroposterior diameter only about 2.5 mm. It is less conspicuous in Dm².

The teeth of the lower jaw vary in much the same way as those of the upper, and show the same differences relative to *B. bison*. There are specimens showing teeth in all stages of wear, from unworn milk molars to permanent molars which have been worn below the level of the lakes. Figure 11 shows the lower teeth of 21189, of moderate age. P₂ is a very simple tooth with an inner and outer furrow, slightly nearer the posterior end of the tooth. P₃ has two open interior valleys and a slight posterior outer furrow, the anterior inner furrow being more or less bilobed in some specimens, especially in 21181. In P₄ there are large open anterior and posterior valleys on the inner side and a smaller one on the anterior inside corner. There is also an outer furrow, situated rather posteriorly. M₁ and M₂ have very narrow crescentic lakes, the outer side of the crescent being slightly pushed in. The outer pillar, when moderately worn, becomes connected with both the protoconid and hypoconid. It is not as large as the inner pillars of the upper molars. In M₃ the pushing in on the base of the crescents is still more prominent. In this tooth there is a slight outer lobe be-

Anterior end
 Greatest height
 measuring
 Posterior end
 back of an
 Front of tooth
 Length of lower
 Length of premolar
 Length of molar
 P₂ Length ..
 P₂ Width
 P₃ Length ..
 P₃ Width
 P₄ Length ..
 P₄ Width
 M₁ Length ..
 M₁ Width ..
 M₂ Length ..
 M₂ Width ..
 M₃ Length ..
 M₃ Width ..
 Length of mandible
 Dm₁ Length
 Dm₁ Width
 Dm₂ Length
 Dm₂ Width
 Dm₃ Length
 Dm₃ Width

* Appendix

TABLE III
MEASUREMENTS OF LOWER JAW AND DENTITION

	B. bison after Hay p. 186	B. bison M. C. Z. 91 after J. A. Allen	B. bison M. C. Z. 102 after J. A. Allen	B. bison M. C. Z. after J. A. Allen	21438	21432	21434	21442	21445	21184	21189	21440	21181	21441	21438	21439	21435	21180	21437	21456
Anterior end to angle of lower jaw	406 mm.	397	382	.....	.....	.....	454	430	.....	.....	430	437	440	.....	.....	415	.....	400	.....	.....
Greatest height of vertical ramus measuring to condyle .....	.....	.....	.....	.....	.....	.....	158	140	.....	.....	150	154	155	..	..	.....	139	163	.....	96
Posterior end of tooth series to back of angle .....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	119	113	.....	.....
Front of tooth series to tip of jaw .....	.....	.....	.....	.....	198	.....	144	142	.....	.....	120	136	120	.....	.....	.....	.....	.....	.....	.....
Length of lower series of cheek-teeth	152	165	153	147	175	186	175	149	.....	180	183	170	180	.....	.....	125*	.....	130	114	70
Length of premolar series	55	.....	.....	.....	60	59	60	54	.....	63	67	60	65	.....	.....	66	.....	.....	.....	.....
Length of molar series	97	.....	.....	.....	116	123	116	95	108	118	116	109	115	.....	.....	117	.....	.....	.....	.....
P ₁ Length	13	.....	.....	.....	.....	14	.....	12	.....	15	.....	16	17	12	17	.....	.....	.....	.....	.....
P ₁ Width	9	.....	.....	.....	.....	10	.....	9	.....	9	.....	9	9.5	9	9.5	.....	.....	.....	.....	.....
P ₂ Length	19	.....	.....	.....	.....	22	.....	18	.....	22	24	21	22	Milk	23	.....	.....	.....	.....	.....
P ₂ Width	11	.....	.....	.....	.....	14	.....	13	.....	9	13.5	14	11	.....	11	.....	.....	.....	.....	.....
P ₃ Length	22	.....	.....	.....	.....	27	.....	21	.....	25	25	23	25	Milk	.....	.....	.....	.....	.....	.....
P ₃ Width	13.5	.....	.....	.....	.....	16	.....	14	.....	9	16	16	13	.....	.....	.....	.....	.....	.....	.....
M ₁ Length	26	.....	29	.....	30	33	28	25	27	30	30	27	31	30	.....	31	.....	.....	36	.....
M ₁ Width	16	.....	18	.....	19	22	23	17	19.5	9	20	20	19	17	.....	18	.....	.....	14	.....
M ₂ Length	32	.....	32	.....	39	36	36	29	33	35	37	32	39	37	40	38	35	.....	.....	.....
M ₂ Width	18	.....	19	.....	19	21	24	20	21	9	20	22	19	16	19	18	15	.....	.....	.....
M ₃ Length	41.5	.....	42	.....	50	49	50	43	48	53	48	47	50	.....	.....	48	.....	.....	.....	.....
M ₃ Width	16	.....	17	.....	16.5	23	23	18	21	20	18	23	16.5	15	.....	16	.....	.....	.....	.....
Length of milk molar series .....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	66	.....	.....
Dm ₁ Length .....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	10	.....	.....
Dm ₁ Width .....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	7	.....	.....
Dm ₂ Length .....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	18	.....	22	.....	22	21	.....
Dm ₂ Width .....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	11	.....	14	.....	11	9.5	.....
Dm ₃ Length .....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	34	.....	.....	39	35	37	45
Dm ₃ Width .....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	15	.....	.....	19	15	15	15

* Approximate.

tween the second and third lobes, but not as well developed as that between the first and second lobes. The third lobe is very simple.

Milk teeth are present in a number of jaws. Dm_3 somewhat resembles permanent P_3 , having two open interior valleys and a single outer one; it is considerably smaller, however. Dm_4 resembles permanent P_4 in size, but differs from it in having the posterior inner valley closed, forming a lake (fig. 12a). Dm_4 is trilobed, having large triangular outer lobes between the first and second and between the second and third main lobes, as well shown in fig. 12a, representing a Dm_4 about to be shed, as can be seen from fig. 12b. When unworn Dm_4 is almost as large as permanent M^3 .

The sequence with which the permanent teeth come into function is as follows: M^1 , M^2 , P^2 , then almost simultaneously P^3 and M^3 , and finally P^4 .

CONCLUSIONS

Bison antiquus, as represented by an excellent series from Rancho La Brea, and by other specimens, is subject to approximately the same sort of individual and sexual variation as is found in the modern species. Individual variation occurs in size and relative measurements of the skull to the extent of about 20 per cent or less, while the sexual difference in these respects is small, apparently less in *B. antiquus* than in *B. bison* or *B. bonasus*. The horn-cores show approximately similar individual variation within a sex, but the average length in females is about 25 per cent less, while the basal circumference is about 33 per cent less, with no individual overlap in either case. From this it is evident that the females have not only smaller, but more slender horns. This corresponds to the condition in the existing species. The variation in general form, curvature, and angle of insertion of the horn-cores is very slight, and these make reliable specific characters.

The dentition varies so little in different species, that specific identification by means of the teeth is almost impossible. The size of the teeth, and the amount of indenting or folding of the enamel walls of the lakes varies to some extent in different species, but it is apparently so variable within a species as to be of very little taxonomic value. In general the teeth of *B. antiquus* have the enamel walls of the lakes more complicated than have modern specimens of *B. bison*.

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OF THE SANTA ANA MOUNTAINS OF
SOUTHERN CALIFORNIA

BY

EARL LEROY PACKARD



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FAUNAL STUDIES IN THE CRETACEOUS
OF THE SANTA ANA MOUNTAINS OF
SOUTHERN CALIFORNIA

BY

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INTRODUCTION

The large number of fossiliferous localities occurring within the Cretaceous beds flanking the western slope of the Santa Ana Mountains afford an unusual opportunity for faunal studies in the Upper Cretaceous of the Pacific Coast. Detailed studies of the faunal successions in this region were carried on by the writer in connection with the work of the University of California Summer Session class in Palaeontology in 1913. Collections in the Cretaceous were made at seventy-two localities, for nearly all of which the stratigraphic position is definitely known. These stations are well distributed throughout the two thousand feet of strata in the section and are situated along a strip about

thirteen miles in length. The large fauna is divisible into three zones, each of which has been designated by the name of a characteristic species. This section may be regarded as a type region for reference of faunal zones of the Chico group.

The writer wishes to thank Professor John C. Merriam for his interest in, and general supervision of, this study, and to acknowledge the assistance given him in the field by Dr. Roy E. Dickerson and the other members of the field party.

REVIEW OF THE LITERATURE

The first recognition of faunal differences in the Cretaceous of California should be credited to W. M. Gabb,¹ who divided the Cretaceous into the Shasta and Chico groups on the basis of faunal differences. C. A. White² in 1885 divided the Shasta group of Gabb into the Knoxville and Horsetown beds. The fauna obtained from White's³ Wallala group, which was then thought to be intermediate in age between that of the Horsetown and Chico, is now considered to be but a phase of the lower Chico.⁴ Dr. T. W. Stanton has studied the California Cretaceous in its various aspects, and has contributed largely to our knowledge of the different faunas.

The classification of the California Cretaceous as given by White remained unchanged until in 1902 F. M. Anderson divided the Knoxville into an upper, or Paskenta horizon, and a lower, less fossiliferous one to which he applied the term Sub-Knoxville.⁵

Anderson recognized two faunal stages in the Chico, under the names of Upper and Lower Chico. His conclusions were derived from compiled and revised lists of species, which were, as he states, "massed from a number of the more significant localities."⁶ Regarding the Horsetown and the Chico Anderson writes that "the transition of faunas is more gradual than it has been in any other basin of the Pacific border; and for that reason the faunas representative of the

¹ Gabb, W. M., *Palaeontology of California*, vol. 2, p. xiii, 1869.

² White, C. A., *On the Mesozoic and Cenozoic Palaeontology of California*, U. S. Geol. Surv. Bull. 15, p. 19, 1885.

³ White, C. A., *On new Cretaceous Fossils from California*, U. S. Geol. Surv. Bull. 22, 1885.

⁴ Willis, Bailey, *Index to the Stratigraphy of North America*, U. S. Geol. Surv. Professional Paper 71, p. 647, 1912.

⁵ Anderson, F. M., *Cretaceous Deposits of the Pacific Coast*, Proc. Calif. Acad. Sci., Third Series, Geol. vol. 2, p. 47, 1902.

⁶ *Op. cit.*, p. 25.

different horizons are not so easily distinguished."⁷ Anderson chose therefore the following localities outside of the Great Valley as typical of the Lower Chico:⁸ San Diego, California, Silverado Cañon, (Santa Ana Mountains) Henley, California, and Phoenix, Oregon. He assigned the type Chico of Chico Creek, Pence's Ranch, Texas Flat, and Tuscan Springs to the Upper Chico. All of these localities are in the upper portion of the Sacramento Valley.

The Silverado Cañon fauna apparently includes only the lowermost fauna from that region. The fauna listed from San Diego, obtained from Point Loma and Point La Jolla, is comparable to the fauna from the lower zone of the Santa Ana Mountains. The different faunas which are considered as equivalent to the upper Chico include the fauna from Chico Creek. It thus appears that Anderson recognized that the Chico Creek fauna represented but a portion of the Upper Cretaceous of California.

A review of the geologic literature dealing especially with the Santa Ana region has been amply covered in a recent paper by Dr. Roy E. Dickerson entitled "The Martinez and Tejon Eocene and Associated Formations of the Santa Ana Mountains."⁹

GEOLOGY OF THE REGION

GENERAL GEOLOGIC RELATIONS

In the rocks of the Santa Ana Mountains the following geological divisions are represented; a basement complex of questionably Triassic age; Upper Cretaceous, Chico; Lower Eocene, Martinez; Upper Eocene, Tejon; the lowermost Miocene, Vaqueros; and alluvium of probable Pleistocene age. The intrusives and the metamorphosed sedimentaries of the basement complex comprising the core of the range are unconformably overlain by the Cretaceous sandstones and conglomerates. Both the Martinez and the Tejon are represented by small remnants, which are shown by Dickerson¹⁰ to be discordant with both the underlying Cretaceous and the overlying Miocene. The latter strata successively overlap the Tejon, Martinez, and Chico, and at Arroyo Trabuco are in contact with the basement complex.

The Cretaceous occurs on both sides of the range. It outcrops on the western flank of the mountains in a band having a maximum width

⁷ *Op. cit.*, p. 25.

⁸ *Ibid.*, p. 26.

⁹ Univ. Calif. Publ. Bull. Dept. Geol., vol. 8, pp. 257-274a, pls. 26-28, 1914.

¹⁰ *Op. cit.*, pp. 263-267.

of about three and one-half miles, tapering to a point at a distance of about thirteen miles to the southeast. On the eastern side of the range the strip is narrower, being about a mile in width and three in length.

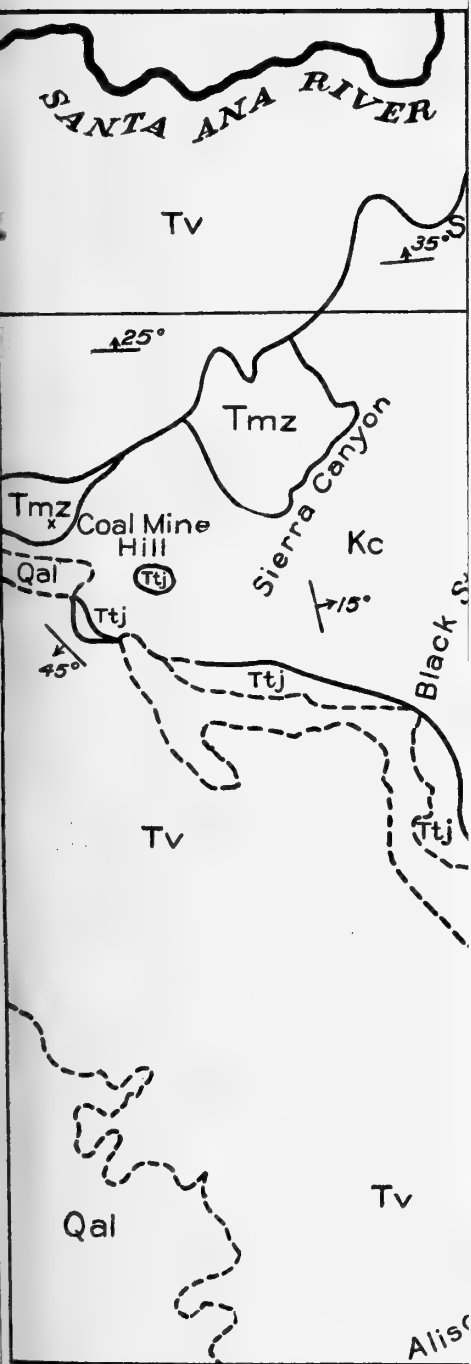
The structure of the Cretaceous of the Santa Ana Mountains appears to be that of an asymmetric anticline, the eastern limb of which has been faulted down and partly concealed by subsequent formations. The strata of the western limb of this fold south of Black Star Cañon have a strike of about N 45° W and a westerly dip of 25° to 30°. On the west side of this cañon the beds are gently inclined, the dip in places not exceeding ten or fifteen degrees. Still farther north the structure becomes complicated by gentle minor folds. North-east of Coal Mine Hill a carbonaceous stratum marks one limb of a small anticline. Coal Mine Cañon, north of Sierra Cañon, is nearly parallel to the axis of a pre-Tejon fold which involved the Martinez and Chico strata.

THE TRABUCO FORMATION

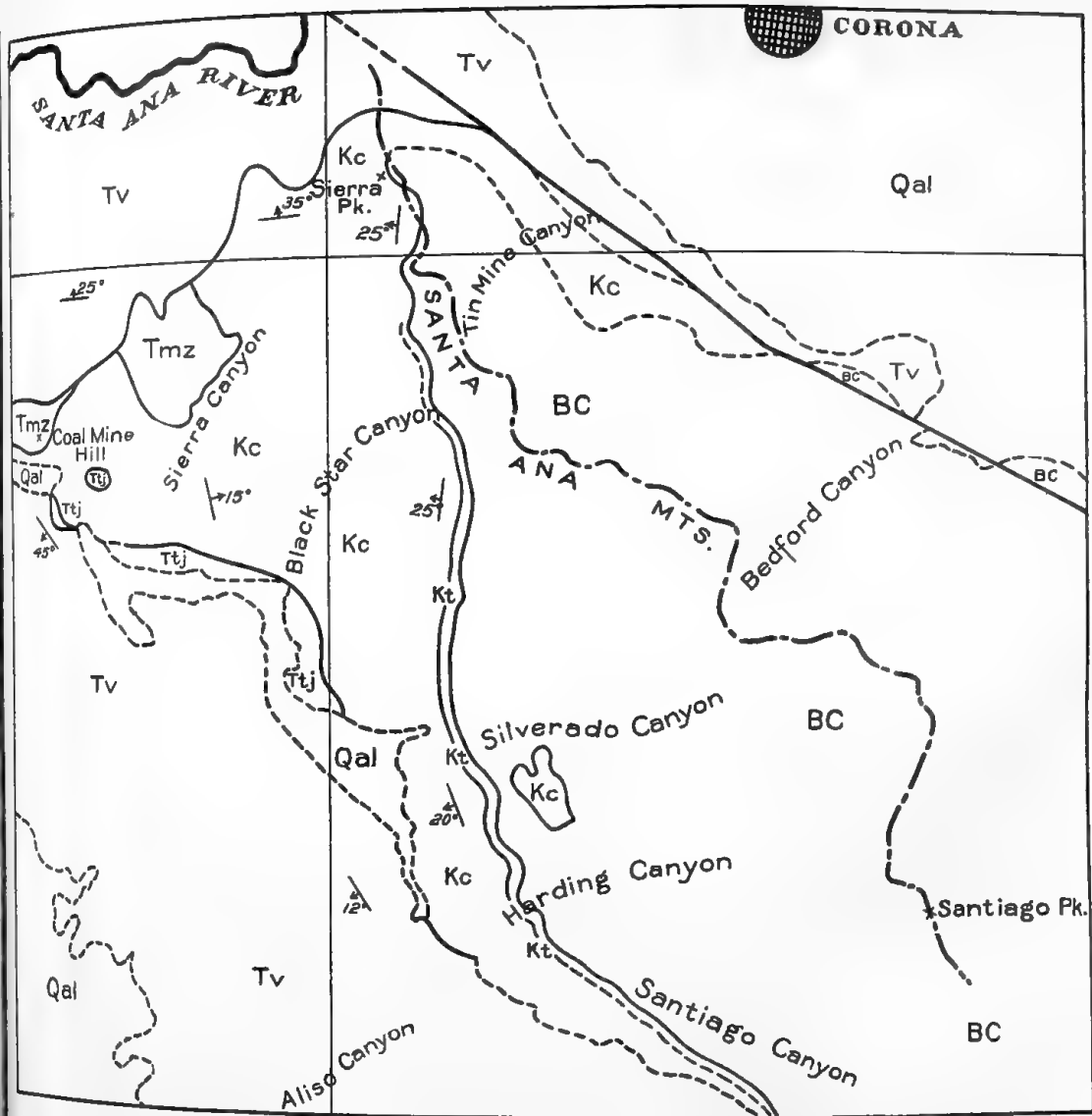
The basement complex comprising the core of the Santa Ana Mountains is unconformably overlain by a massive red conglomerate, which is traceable as a distinct mapable unit for a distance of about ten miles along the strike. It occurs as a narrow belt three or four hundred feet in width, extending from North Star Cañon nearly to Trabuco Cañon. The term Trabuco formation is here proposed as a local name for these red beds so well exposed along the western flank of the Santa Ana Mountains.

The best section of the Trabuco formation may be seen in Harding Cañon, where the beds have a dip of about 45° S and a strike of N 15° W. The metamorphosed sedimentaries of the basement complex dip about 45° N and strike N 15° W. In places the low dip carries the red basal conglomerates some distance up the slope of the ridges into the area of the basement complex in such a way that small isolated patches of the beds may be found, separated by erosion from the main mass, or connected with it by a thin veneer of residual gravels.

The loosely cemented conglomerates of the Trabuco formation develop upon weathering a rounded topography which is in marked contrast to the abrupt cliffs formed by the gray conglomerates of the overlying Chico. The conglomerates of the basal Chico lie in apparent conformity upon those of the Trabuco, but in most localities the change from the red to the gray beds is very abrupt, suggesting an erosion interval. Direct evidence for such a structural break is lacking. That



Sketch map of a portion of the Santa Ana River area showing terrace deposits; Tv, Tertiary Miocene; Ttj, Tertiary Tertiary; Qal, Quaternary; BC, Basement Complex.



Sketch map of a portion of the Santa Ana Mountains, California, a part of the Corona Quadrangle. Qal, Alluvium and Pleistocene terrace deposits; Tv, Tertiary Miocene; Ttj, Tertiary Tejon Eocene; Tmz, Tertiary Martinez Eocene; Kc, Cretaceous Chico; Kt, Cretaceous Trabuco; BC, Basement Complex. Scale, $\frac{1}{2}$ inch = 1 mile.



Handwritten notes at the bottom of the page, including the number '100' and the word 'Station'.

the Chico conglomerates are conformable upon those of the Trabuco appears to be indicated at one locality where a gradation from a red to a gray conglomerate was noted.

These red Trabuco conglomerates are composed of both angular and water-worn boulders varying in size up to those having a diameter of three feet. The boulders represent a considerable range of rock types, the majority of the igneous rocks being basic. In places subordinate bands of red sandstone occur interbedded with the conglomerates.

The peculiar color, the angular form of most of the pebbles and sand grains, and the lack of marine fossils suggests that the Trabuco formation was deposited upon a narrow coastal plain, by torrential streams arising in a mountainous region but a short distance to the eastward. After about two hundred feet of this material had been laid down, marine conglomerates of the basal Chico accumulated within the waters of the transgressing sea.

The age of the Trabuco horizon is not definitely known, since as yet it has yielded no fossils. Judging from its stratigraphic relations the formation is probably but slightly older than the Chico group and presumably represents some phase of the pre-Chico Cretaceous.

THE CHICO GROUP

Resting with apparent conformity upon the Trabuco formation is a series of conglomerates differing from those of the lower formation, in the lighter color of the matrix, in the firmer cementation, in the greater abundance of pebbles of quartzites and slates, and in the inclusion of marine fossils in the matrix and in the rounded boulders. The fossils from the boulders comprise fragments of *Inoceramus* and of an indeterminate gastropod, suggesting the occurrence of earlier Cretaceous deposits now completely removed by erosion.

The conglomerate resting upon the Trabuco grades upward into coarse, light-colored sandstones with subordinate strata of hard, fine-grained calcareous sandstone bearing a characteristic fauna. Following these are several hundred feet of laminated, bluish shales, often containing limestone nodules. The nodules are occasionally fossiliferous. Above the shales the strata again become coarser, being composed of sandstones, which in places grade laterally into conglomeratic lenses. These beds are succeeded by a series of alternating strata of sandstone and shale, which in turn are replaced in the upper portion of the section by hard, fine-grained, calcareous sandstones, fine tan-colored

shales and lenses of carbonaceous shales, interstratified in places with seams of coal of an inferior quality.

The most complete section of the Chico group was obtained along the divide between Santiago and Aliso cañons, the details of which are given below. This section in descending order follows.

SECTION OF THE CRETACEOUS ALONG THE SANTIAGO-ALISO DIVIDE

Description of the Lithology	Faunal Zones	Estimated Thickness
Fine-grained, calcareous, tan shales		65 feet
Covered by Vaqueros		120
Tan sandstone intercalated with a resistant, laminated, micaceous, gray, sandstone	Tellina ooides zone	130
Hard, gray, micaceous sandstone		45
Brownish-gray, sandy shales		140
Coarse white sandstone, with a few rounded pebbles	Turritella pescaderoensis zone	60
Light-colored conglomerate, alternating with bands of gray sandy shale, weathering to a dark red		200
Fine-grained, steel-gray shale with lenses of calcareous sandstone		125
Fine-grained gray shale with calcareous nodules		550
Laminated sandstone, slightly conglomeratic, interbedded with gray shale	Actaeonella oviformis zone	50
Gray, conglomeratic sandstone		100
Heavy, gray conglomerates		200
Total thickness of the Chico group		1600
Trabuco formation		
Red conglomerates with subordinate bands of red sandstone		200
Total thickness of the Chico and the Trabuco		1800

FAUNA

GENERAL CHARACTER

The Cretaceous fauna recently obtained from the Santa Ana Mountains includes eighty species and varieties of Pelecypoda, thirty-three of Gastropoda, eleven of Cephalopoda, one of Scaphopoda, besides a few specimens belonging to the Molluscoidea, Vermes, Echinodermata, Arthropoda and Vertebrata. The entire fauna comprises one hundred and thirty-one forms, of which twenty-two are new. The fauna from this region is further increased by other workers who obtained in the same field a number of species not recognized in our collections.

The bivalves are represented by the largest number of species as well as by the largest number of individuals of all the groups enumerated above. *Trigonoarca*, a genus commonly collected in the Trichinopoli group of the Indian Cretaceous, is represented in the Santa Ana Mountains by three new species. Two other genera, *Liopistha* and *Gastrochaena*, have not heretofore been reported from the Cretaceous of California. Members of the genera *Tellina*, *Crassatellites*, *Meretrix*, *Lima*, and *Pecten* are frequently obtained from the Santa Ana region.

The gastropods are most abundantly represented by members of the families Turritellidae, Aporrhaidae and Volutidae. The Turritellas are very abundant in this southern region, whereas in more northern Upper Cretaceous localities of California and especially in Washington and British Columbia they are rare.

The cephalopods are represented in our collections by a number of imperfect specimens. Two or possibly three large nautiloids, resembling certain Indian species, occur in calcareous nodules within the lower shales. Several ammonoids have been found within these shales. Of these forms the genus *Schloenbachia* is most commonly obtained.

FAUNAL ZONES

Faunal studies of marine life carried on within the North Sea,¹¹ at Woods Hole¹² and elsewhere show intimate relationship between the distribution of marine organisms and the factors of their environment. The character of the bottom, or in geologic terms the type of deposition, determines in a large measure the facies of a given fauna. Thus the different types of bottom are characterized by different faunal associations.

It seems highly probable that under conditions of littoral deposition a sand-dwelling fauna would be replaced by a quite different fauna if conditions of sedimentation were changed. Upon the return of favorable conditions the earlier fauna might again occupy the same region. This effect of the changing conditions is seen in the vertical distribution of a number of large gastropods belonging to the Volutidae. These forms are most abundant within the Santa Ana Mountains in the "lower" shales, and apparently were forced to migrate during

¹¹ Peterson, C. G. Joh., Valuation of the Sea 11, Report of the Danish Biological Station 21, pp. 1-44, 1915.

¹² Sumner, F. B., Osburn, R. C., Cole L. J., and Davis, B. M., A biological survey of the waters of Woods Hole and vicinity, Bull. U. S. Bur. Fish., 31, pp. 1-860, 1913.

the time that certain sandstones were being deposited, appearing again in the shales above.

Strata that yield a fauna possessing distinctive characters due to evolutionary change rather than to environmental difference may be designated a faunal zone. The distinctive character of the zone is due, then, primarily to the species whose vertical range is restricted to that zone, and secondarily to those species which having reached their height of development are often more abundant than at any other period in the life of the species. The zone may thus be said to possess restricted and characteristic species, besides many unimportant long-range forms.

The fossiliferous Cretaceous rocks of the Santa Ana Mountains are divisible into three zones, each of which will be designated by the name of a representative species.

The lowermost zone of the Cretaceous of this southern region is named the *Actaeonella oviformis* zone from the presence of a very characteristic gastropod. The fauna associated with this species occurs in the basal conglomerate and sandstone, which lie below the "lower" shales, representing about three hundred and fifty feet of sediments. The fauna obtained from these beds is based upon collection made at the following University of California localities: 2130, 2131, 2134, 2139, 2140, 2141, 2142, 2143, 2191.

This zone is characterized by the abundance of *Actaeonella oviformis*, which appears to be restricted to the zone and by *Pecten operculiformis*, *Pecten californica*, *Trigonoarca*, n. sp. *c* and *Astarte*, n. sp. *a* which are occasionally collected within the higher zones although they are nowhere so abundant as within these lower beds (see Table 1).

The faunal zone above the *Actaeonella oviformis* zone is named after its most characteristic species, *Turritella pescaderoensis* Arnold. The strata through which this fauna ranges include about eleven hundred feet of shale, sandstone and conglomerate.

This zone includes two faunas which are distinguished mainly by characters due to differences in bathymetric conditions. The shales just above the basal conglomerate and sandstone yield a number of gastropods and cephalopods not found abundantly in the coarser sediments of the underlying or overlying strata. This deeper-water fauna appears to be replaced by a fauna of shallower water characterized by the abundance of such species as *Turritella pescaderoensis*, *Crassatellites lomana*, and *C. conradiana* var. *tuscanica*, but it again appears in a slightly modified form in certain higher shale beds. This deeper-

water faunal phase is best represented at the following University of California localities: 2136, 2147, 2153, 2156, 2166, and 2170.

The deeper-water phase of the *Turritella pescaderoensis* zone is noteworthy for the number of species of the Volutidae and Aporrhaidae that it contains. *Opis triangulata* commonly occurs in the shales at a horizon about the middle of this zone. Several poorly preserved ammonids and nautiloids occur more abundantly here than elsewhere.

The shallower-water phase of the *Turritella pescaderoensis* zone replaces in part the fauna from the shales below. The strata through which this assemblage ranges comprise about six hundred feet of sandstones, heavy conglomerates, and occasional subordinate bands of shale. The following University of California localities have been selected as being characteristic of this phase of the *Turritella pescaderoensis* zone: 2135, 2146, 2148, 2150, 2151, 2152, 2159, 2160, 2162, 2167, and 2172. *Crassatellites lomana* and *C. conradiana* var. *tuscan*a together with *Turritella pescaderoensis* form a large proportion of the fauna of a fossiliferous stratum that is traceable for a distance of several miles.

The uppermost zone is known as the *Tellina ooides* zone. The fauna is characterized by the great abundance of specimens of *Tellina* and occurs within the uppermost three hundred feet of the section. The strata consist primarily of fine-grained sandstones. The fauna from these upper beds is imperfectly known, due to the concealment of much of this part of the formation by the overlying Vaqueros. The fauna of this zone listed in the table below was obtained from the University of California localities 2168 and 2169.

This zone yields a large number of pelecypods and relatively few gastropods. The lack of cephalopods is noteworthy, especially since fragments of ammonites are frequently collected in the beds below this horizon. *Perissolax brevirostris* is quite characteristic of the zone. *Meekia sella* was found only within these uppermost beds, although it has been reported elsewhere from the lower Chico.

The fauna of the different zones is indicated in the table below. A fifth column is given for those species whose stratigraphic position is unknown. An asterisk indicates species characteristic of the zone in which this convention appears.

TABLE I

LIST OF CRETACEOUS SPECIES FROM THE SANTA ANA MOUNTAINS

	Actaeonella oviformis zone	Deep water phase of Turritella pesca- deroensis zone	Shallow water phase of Turritella pesca- deroensis zone	Tellina ooides * zone	Zonal position uncertain
<i>Acila truncata</i> (Gabb)	×	×	×	
<i>Anatina</i> (?)	×		
<i>Anomia lineata</i> Gabb.	×		×
<i>Astarte</i> , n. sp. <i>a</i>	*	×	×
<i>Astarte</i> , n. sp. <i>b</i>	×
<i>Astarte</i> , sp. <i>c</i>	×
<i>Cardium</i> , sp. <i>a</i>	×
<i>Cardium</i> , sp. <i>b</i>	×
<i>Cardium</i> , sp. <i>c</i>	×
<i>Cardium</i> , cf. <i>remondianum</i> Gabb	×
<i>Clisocolus dubius</i> (Gabb)	×	×	×	×
<i>Coralliochama</i> , sp.	×
<i>Corbula traskii</i> Gabb	×	?
<i>Crassatellites lomana</i> (Cooper)	×	*
<i>Crassatellites conradiana</i> , var. <i>tus-</i> <i>cana</i> (Gabb)	×	×	*	×
<i>Cucullaea</i> , n. sp. <i>a</i>	×
<i>Cucullaea</i> , n. sp. <i>b</i>	×
<i>Cucullaea truncata</i> (Gabb)	×	×	×	×
<i>Cucullaea decurtata</i> (Gabb)	×	?
<i>Cucullaea ponderosa</i> Whiteaves	×
<i>Dosinia inflata</i> Gabb	×	×	?
<i>Exogyra</i> , n. sp. <i>a</i>	*	×
<i>Exogyra</i> , sp. <i>b</i>	*	×	×
<i>Gastrochaena</i> , sp.	×
<i>Glycymeris pacificus</i> (F. M. Anderson)	×
<i>Glycymeris veatchii</i> (Gabb)	×	×	×	×
<i>Homomya</i> , n. sp. <i>a</i>	×
<i>Inoceramus</i> , cf. <i>digitatus</i> (Sowerby)	×
<i>Inoceramus</i> , sp.	×
<i>Inoceramus whitneyi</i> Gabb	×
<i>Isocardia</i> , sp.	×
<i>Lima</i> , sp. <i>b</i>	×
<i>Lima</i> , sp. <i>c</i>	×
<i>Lima microtis</i> Gabb	×
<i>Lima</i> , cf. <i>shastaensis</i> Gabb	×
<i>Liopistha anaana</i> (F. M. Anderson)	×
<i>Martesia</i> (?) <i>parvula</i> Whiteaves	×
<i>Meekia sella</i> Gabb	×
<i>Meretrix arata</i> Gabb	×
<i>Meretrix lens</i> Gabb	×	×	×
<i>Meretrix nitida</i> Gabb	×	×	×

TABLE I—(Continued)

	Actaeonella oviformis zone	Deep water phase of Turritella pesca- deroensis zone	Shallow water phase of Turritella pesca- deroensis zone	Tellina ooides zone	Zonal position uncertain
PELECYPODA—					
Meretrix, sp. <i>a</i>	×	×
Meretrix (?) sp. <i>b</i>	×
Modiolus siskiyouensis Gabb	×
Modiolus, sp. <i>a</i>	×
Mytilus, sp.	×
Nemodon vancouverensis (Meek).....	×
Opis triangulata (Cooper)	×
Ostrea, n. sp. <i>a</i>	×	*	×
Ostrea, n. sp. <i>b</i>	×	*
Ostrea, n. sp. <i>c</i>	×
Ostrea brewerii Gabb	×	×
Panope, n. sp. <i>a</i>	×
Pecten californicus Gabb	×
Pecten operculiformis Gabb	×
Pecten, sp. <i>a</i>
Pecten, sp. <i>b</i>	×
Pecten (?), sp. <i>c</i>	×
Pinna, cf. calamitoides Schumard	×	×
Plicatula, n. sp. <i>a</i>	×
Siliqua, n. sp. <i>a</i>	×
Solen, sp.	×	×
Spisula ashburnerii (Gabb)	×	*
Spisula chicoensis Packard	×
Spisula gabbiana (F. M. Anderson)	×
Spondylus, sp.	×
Spondylus, n. sp. <i>a</i>	×
Tellina, n. sp. <i>a</i>	*
Tellina, n. sp. <i>b</i>	×
Tellina, sp. <i>c</i>	×	×
Tellina, sp. <i>d</i>	×	×	×
Tellina ashburnerii Gabb	×
Tellina, cf. hoffmanniana Gabb	×	×
Tellina ooides Gabb	×	×
Teredo, sp.	×
Trigonoarca, n. sp. <i>a</i>	×
Trigonoarca, n. sp. <i>b</i>	×
Trigonoarca, n. sp. <i>c</i>	×
Trigonia evansana Meek	×	×	×	×
Trigonia tryoniana Gabb	×
GASTROPODA—					
Acmaea, sp.	×	?
Actaeonella oviformis Gabb	*	?

TABLE I—(Continued)

	Actaeonella oviformis zone	Deep water phase of Turritella pesca- deroensis zone	Shallow water phase of Turritella pesca- deroensis zone	Tellina ooides zone	Zonal position uncertain
<i>Alaria condoniana</i> (F. M. Anderson)	×
<i>Alaria falciformis</i> (Gabb)	×
<i>Amauropsis</i> , n. sp. <i>a</i>	×	×
<i>Amauropsis oviformis</i> Gabb	×	×
<i>Aporrhais</i> , n. sp. <i>a</i>	×
<i>Aporrhais</i> , n. sp. <i>b</i>	×
<i>Aporrhais</i> , n. sp. <i>c</i>	×
<i>Bullaria</i> , n. sp. <i>a</i>	×
<i>Cerithium</i> , n. sp. <i>a</i>	×
<i>Cerithium</i> , sp.	×
<i>Cinulia obliqua</i> Gabb	×	*
<i>Chrysodomus</i> , sp. <i>a</i>	×
<i>Epitonium</i> , n. sp. <i>a</i>	×
<i>Eulima</i> , sp.	×
<i>Fusus</i> (?), sp. <i>a</i>	×
<i>Fusus</i> (?), sp. <i>b</i>	×
<i>Gyrodos expansa</i> Gabb	×	×
<i>Lyria</i> (?)	×	×	×
<i>Lysis</i> (?), n. sp. <i>a</i>	×
<i>Margarites ornatissima</i> (Gabb)	×
<i>Natica</i> , sp. <i>a</i>	×
<i>Perissolax brevirostris</i> Gabb	×
<i>Potamides</i> , sp.	×
<i>Turritella</i> , n. sp. <i>a</i>	×
<i>Turritella</i> , n. sp. <i>b</i>	×
<i>Turritella</i> , sp. <i>c</i>	×
<i>Turritella</i> , sp. <i>d</i>	×
<i>Turritella pescaderoensis</i> Arnold	×	×	*	×
<i>Volutoderma</i> , sp. <i>a</i>	*
<i>Volutoderma</i> , n. sp. <i>b</i>	*	×
<i>Volutoderma</i> , n. sp. <i>c</i>	*	×
<i>Volutoderma</i> , cf. <i>californica</i> Dall	×
SCAPHOPODA—					
<i>Dentalium</i> , sp.	×
CEPHALOPODA—					
<i>Ammonites</i> , sp. <i>a</i>	×
<i>Ammonites</i> , sp. <i>b</i>	×
<i>Ammonites</i> , sp. <i>c</i>	×
<i>Ammonites</i> , sp. <i>d</i>	×
<i>Baculites chicoensis</i> (Trask)	×
<i>Hamites</i> (?)	×
<i>Helicancylus</i> , sp.	×

TABLE I—(Continued)

	Actaeonella oviformis zone	Deep water phase of Turritella pesca- deroensis zone	Shallow water phase of Turritella pesca- deroensis zone	Tellina ooides zone	Zonal position uncertain
<i>Nautilus</i> , sp. <i>a</i>	×
<i>Nautilus</i> , sp. <i>b</i>	×
<i>Placentoceras californicum</i> F. M. An- derson	×
<i>Schloenbachia knighteni</i> F. M. An- derson	×
ASTEROIDEA—					
<i>Ophioglypha</i> , n. sp. <i>a</i>	×
ECHINOIDEA—					
<i>Schizaster</i> , n. sp. <i>a</i>	×
BRACHIOPODA—					
<i>Terebratula</i> , sp.	×
VERMES—					
Worm tubes	×
CRUSTACEA—					
Crustacean	×
PISCES—					
<i>Lamna</i> , sp.	×

To this list may be added the following species that have been reported by Bowers,¹³ Cooper,¹⁴ and Anderson¹⁵ from the Santa Ana Mountains. The stratigraphic situation of these forms is uncertain.

<i>Asaphais multicostata</i> Gabb	<i>Globiconcha remondii</i> Gabb
<i>Clisocolus cordatus</i> Whiteaves	<i>Potamides tenuis</i> Gabb
<i>Crenella santana</i> Cooper (?)	<i>Scobinella dilleri</i> White
<i>Cucullaea bowersiana</i> Cooper	<i>Turritella seriatum-granulata</i> Roemer
<i>Cucullaea inernis</i> Gabb	<i>Acanthoceras compressus</i> F. M. An- derson
<i>Pecten traskii</i> Gabb	<i>Ammonites stoliczkanus</i> Gabb
<i>Pholadomya sonorensis</i> Gabb	<i>Ammonites traskii</i> Gabb
<i>Cominella lecontei</i> White	<i>Baculites fairbanksi</i> Anderson
<i>Fulgar hilgardi</i> White	

¹³ Bowers, Dr. Stephen, Orange County, 10th Annual Report State Mineralogist, California State Mining Bureau, p. 399, 1890.

¹⁴ Cooper, J. G., Catalogue of California Fossils, California State Mining Bureau, Bull. 4, pp. 33, and 36–51, 1894.

¹⁵ Anderson, F. M., Cretaceous Deposits of the Pacific Coast, Proc. Calif. Acad. Sci., Third Series, Geol., vol. 2, pp. 27–32, 1902.

<i>Desmoceras sugatum</i> (Forbes)	<i>Placenticerias pacificum</i> J. P. Smith
<i>Lytoceras jacksonense</i> F. M. Anderson	<i>Schloenbachia knighteni</i> Anderson
<i>Nautilus texanus</i> Schumard	<i>Terebratula abesa</i> Gabb
<i>Placenticerias californicum</i> F. M. Anderson	

The relationships of the above defined zones are shown in summary in Table II.

TABLE II

	Actaeonella oviformis zone	Turritella pesca- deroensis zone		Tellina ooides zone	Chico Creek fauna
		Deep water phase	Shallow water phase		
Number of forms	65	25	41	26	79
Number of determined species	47	16	28	18	79
Number of determined species ap- pearing in the Actaeonella ovi- formis zone	47	11	18	4	12
Number of determined species ap- pearing in the Turritella pes- caderoensis zone. Deep water phase	11	16	13	7	6
Number of determined species ap- pearing in the Turritella pes- caderoensis zone. Shallow water phase	18	13	28	12	16
Number of species appearing in the Tellina ooides zone	4	7	12	18	17

RELATION TO OTHER CRETACEOUS FAUNAS OF CALIFORNIA

Anderson recognized the Chico affinities of the fauna obtained in Silverado Cañon on the western slope of the Santa Ana Mountains, but more recent collecting has revealed a large number of species as yet unknown from the typical Chico of northern California. The majority of the forms peculiar to the southern fauna occur in the lowermost beds of that region, suggesting that this stage represents a lower horizon than that known at Chico Creek. This raises a question as to the definition of the beds of the Chico and also as to reasons for the difference between the faunas of the Chico and the Santa Ana Mountains.

In considering the relation between the faunal stages of the typical Chico and the Cretaceous of the Santa Ana Mountains it is necessary to review briefly the relationships of the Chico fauna of Shasta and Tehama counties to that of the underlying Horsetown.

The apparent conformable sequence of beds of the Shasta-Chico series as exposed on Elder and Cottonwood Creeks in Tehama and Shasta counties, together with the recognized faunal continuity make the definition of the different groups difficult. Diller and Stanton who have most carefully considered this question make the following statement: "The faunas of adjacent beds, however, are so bound together by many common species that there is no palaeontologic break anywhere within the series."¹⁶

The Knoxville may for the purposes of this paper be defined in the words of Stanton as "the Aucella-bearing Cretaceous beds on the Pacific Coast of the United States."¹⁷ No specimens of *Aucella* have been reported from the Santa Ana region and therefore this phase of the Cretaceous need not be discussed further.

The Horsetown was first defined in a paper by Charles A. White entitled "Notes on the Mesozoic and Cenozoic Palaeontology of California."¹⁸ On page 19 of this paper he writes:

I shall therefore, for the present, retain the name Shasta group in the general sense in which it was used by the geologists of the California survey; but for purposes of convenience in references which I must necessarily make in this article to those divisions, I shall designate them as the Horsetown beds and the Knoxville beds, respectively. These names are suggested by the localities from which the best collections of fossils of each division were obtained.

On the next page he states regarding the fauna: "It is especially rich in Cephalopoda, as will appear by referring to the California reports, where the fossils of this division are recorded as coming from "The North Fork of Cottonwood Creek, Horsetown, etc." A few sentences below this White lists thirteen of Gabb's species which he would exclude from the Horsetown because of their occurrence at doubtful Horsetown localities. Five of these, *Potomides diadema* Gabb, *Ringinella polita* Gabb, *Liocium punctatum* Gabb and *Lima shastaensis* Gabb are later reported by Anderson¹⁹ from the Horsetown, although their occurrence is not definitely given. It thus appears that the type section of the Horsetown beds includes beds of the Shasta

¹⁶ Diller, J. S. and Stanton, T. W., The Shasta-Chico Series, Bull. Geol. Soc. Am., vol. 5, p. 464, 1894.

¹⁷ Stanton, T. W., The Fauna of the Knoxville beds, U. S. Geol. Surv. Bull. 133, p. 12, 1895.

¹⁸ White, C. A., U. S. Geol. Surv. Bull. 15, pp. 19-20, 1885.

¹⁹ Anderson, F. M., Cretaceous Deposits of the Pacific Coast, Proc. Calif. Acad. Sci., Third Series, Geol., vol. 2, p. 41, 1902.

group recognized by the California Survey and exposed on the North Fork of the Cottonwood Creek and at the locality at Horsetown. In 1888 Diller and Stanton²⁰ state:

At Horsetown and Texas springs, however, only a few miles northeast of the Cottonwood section, many fossils have been found that evidently belong very near the top of the Horsetown beds. Lists of species from these localities showing a commingling of the Horsetown and Chico faunas have already been published.

Yet in 1901 Stanton is quoted by Merriam²¹ in regard to a John Day, Oregon, fauna to the effect that

A similar fauna, with some additions, occurs in the sandstones at Texas Springs and near Horsetown, Shasta County, California, and has been regarded as proof of the blending of the Shasta and Chico faunas, partly because the beds at Horsetown had long been thought to belong to Gabb's Shasta group and had even given the name, Horsetown beds, to the upper division of the Shasta. It is evident, however, from White's somewhat vague definition of the Horsetown beds, that the term was meant to include the strata immediately above the Knoxville that contain the fauna so well developed on the north fork of Cottonwood Creek, in the neighborhood of Ono, and which really has no close relationship with this basal Chico fauna of Texas Springs, Horsetown, and elsewhere.

As far as the writer is aware, this phase of the Shasta-Chico problem has not been discussed elsewhere.

Such an interpretation is in accord with an earlier statement made by Diller and Stanton²² to the effect that the Chico beds extend from "a short distance above the mouth of Hulen Creek to Gas Point," for, in the writer's opinion, the fauna from the locality on Hulen Creek is very closely related to the one near Horsetown, but it is not considered that these represent Chico faunas.

The strata at the Hulen Creek locality just above its confluence with the North Fork of the Cottonwood are composed of conglomeratic sandstones lying apparently conformably upon sandy shales, which but a short distance stratigraphically below contain a typical Horsetown fauna. These psephitic strata grade above into shales similar to those just below. These upper shales grade upward into a massive conglomerate of several hundred feet in thickness which outcrops in the gorge just below the junction of Hulen and Cottonwood creeks. These conglomerates have yielded the writer no determinable fossils. The

²⁰ Diller, J. S., and Stanton, T. W., *op. cit.*, p. 445.

²¹ Merriam, John C., A Contribution to the Geology of the John Day Basin, Univ. Calif. Publ. Bull. Dept. Geol., vol. 2, pp. 283, 284, 1901.

²² Diller, J. S., and Stanton, T. W., *op. cit.*, p. 444.

base of these beds just below the mouth of Hulen Creek might well be taken as the base of the Chico group. This apparently agrees with White's original idea of the location of the base of that group judging from the fauna obtained above and below the horizon.

The differences of opinion as to the location of the base of the Chico group tend to substantiate the view of Diller and Stanton²³ regarding the stratigraphic continuity of the Shasta-Chico series, and show the necessity of detailed faunal studies within this region before the Horsetown and Chico faunas can be clearly defined. Regardless of the final decision on this point, it seems advisable for the purposes of this paper to consider the fauna obtained at Horsetown and its correlative on Hulen Creek as uppermost Horsetown.

In compiling a list of Horsetown species for comparison with the fauna from the Santa Ana Mountains only those species have been included that are known to have come from the Horsetown beds as defined above. Such a procedure considerably reduces the published Horsetown fauna.

A comparison of such a list with the faunal list from the Santa Ana Mountains reveals the following species in common: *Cucullaea truncata* Gabb, *Nemodon vancouverensis* (Meek), *Trigonia evansana* Meek, *Pecten operculiformis* Gabb. These species have a long range, occurring in the Chico of Chico Creek. From this very small representation of common forms it would appear that the latter fauna is not the equivalent of the Horsetown as it is now imperfectly known.

The term Chico was first used by Gabb in a paper read before the National Academy of Sciences in August, 1868.²⁴ The type locality as designated by Gabb in the *Palaeontology of California*²⁵ is very indefinite, including beds most extensively represented in Shasta and Butte counties, California. The group was named for Chico Creek, along which a number of fossiliferous localities occurred.

Recent studies made by C. K. Studley show that the three fossiliferous localities on Chico Creek contain faunas so closely related that they may be considered as a unit.²⁶ The faunas already published by Gabb²⁷ and Turner²⁸ have been greatly increased through the collec-

²³ *Op. cit.*, p. 464.

²⁴ Gabb, W. M., *Palaeontology of California*, vol. 2, p. xii, 1869.

²⁵ *Op. cit.*, p. xiii-xiv.

²⁶ Studley, C. K., MS thesis, University of California, 1914.

²⁷ Gabb, W. M., *Palaeontology of California*, vols. 1 and 2, 1864-1899.

²⁸ Turner, H. W., The rocks of the Sierra Nevada, Fourteenth Annual Report U. S. Geol. Surv., pt. 2, p. 460, 1892-1893.

tions made by Mr. Studley. The two published lists supplemented by Studley's list are taken as the basis of comparison with the fauna from the Santa Ana Mountains.

A comparison of these faunas reveals the following species in common between Chico Creek and the Santa Ana Mountains;

<i>Acila truncata</i> (Gabb)	<i>Spisula chicoensis</i> Packard
<i>Anomia lineata</i> Gabb	<i>Spisula gabbiana</i> (Anderson)
<i>Clisocolus dubius</i> (Gabb)	<i>Tellina ashburnerii</i> Gabb
<i>Crassatellites conradiana</i> , var. <i>tus-</i>	<i>Tellina hoffmanniana</i> Gabb (?)
<i>cana</i> (Gabb)	<i>Tellina ooides</i> Gabb
<i>Cucullaea truncata</i> (Gabb)	<i>Trigonia evansana</i> Meek
<i>Dosinia inflata</i> (Gabb)	<i>Alaria falciformis</i> (Gabb)
<i>Glycymeris veatchii</i> (Gabb)	<i>Cinulia obliqua</i> (Gabb)
<i>Inoceramus whitneyi</i> Gabb	<i>Gyrodes expansa</i> Gabb
<i>Meekia sella</i> Gabb	<i>Perissolax brevirostris</i> Gabb
<i>Meretrix lens</i> Gabb	<i>Volutoderma californica</i> Dall
<i>Meretrix nitida</i> Gabb	<i>Baculites chicoensis</i> Trask
<i>Spisula ashburnerii</i> (Gabb)	

The number of species in common between the Santa Ana Mountains and Chico Creek represent but about thirty-one per cent of the number of determined species of the southern fauna, being nearly the same per cent of the Chico Creek fauna. This small per cent of identical species from the two localities is due in part to the fact that the southern fauna, composed of three faunal zones, is compared with the fauna from Chico Creek, represented probably by a single zone. Seventeen out of the eighteen described species from the *Tellina ooides* zone of the Santa Ana Mountains appear in the above list of common species. On the other hand, there are but twelve out of twenty-eight described species from the *Aetaeonella oviformis* zone of the southern fauna occurring at Chico Creek.

The much larger number of species in common between these localities than was noted above in the comparison with the Horsetown fauna indicates that the southern fauna is equivalent to at least a part of the Chico from Chico Creek.

The faunal differences may be more apparent than real, for the fauna from Chico Creek is but imperfectly known and will be undoubtedly increased by subsequent workers. Nevertheless the differences demand consideration.

It appears to be the consensus of opinion that differences of temperatures due to the geographic positions of these two localities were not as great during the Cretaceous as at present. This factor would

therefore have had but little weight in determining the character of the Chico faunas. Temperature would be a factor in so far as it was associated with oceanic currents, the courses of which are determined largely by the distribution of land and water.

There appears to be little evidence that salinity played an important role in determining the peculiar features of these two faunas, for neither in the Santa Ana Mountain basin nor in that of the Sacramento Valley do we find indications of brackish-water conditions, except very locally during comparatively short periods of coal formation.

The direct and indirect effect of the type of the bottom is a generally recognized factor influencing the life upon the floor of the sea. A comparison of these basins of deposition reveals the fact that the strata of the more southern one are more conglomeratic than are those of the northern basin. The fauna as well as the lithology indicates that the Cretaceous beds of the Santa Ana Mountains were deposited largely within shallow waters. The species types from Chico Creek and the considerable amounts of carbonaceous material also argue for shallow-water conditions within the northern basin. It thus appears that the faunal differences can not definitely be attributed to differences in the character of the bottom. However, to a collector of Recent Mollusca this may not appear very conclusive, for quite diverse faunas exist under present conditions on types of sediments in which after induration the differences would probably not be particularly marked.

The areal extent of the Upper Cretaceous sea is such as to suggest that there was direct communication between these two basins of deposition. If this is a correct inference, isolation did not play an important part in causing the faunal dissimilarities.

The differences in environment, then, resolve themselves primarily into the effects of temperature due to oceanic currents, and possibly to differences of types of sediments. These all directly or indirectly were affected by the distribution of land during this period. That the shore line during the Upper Cretaceous was only a short distance east of the present summit of the Santa Ana Range is inferred by the type of sediments composing the Chico group of this region, and by the absence of Chico strata at any considerable distance east of those mountains. The Trabuco formation and the lower part of the Chico have been described above as being decidedly conglomeratic, both containing boulders apparently derived from rocks similar to those

comprising the core of the present range. The character of the contact of the Trabuco formation with the basement complex, as shown in detail and by areal mapping, indicates a land surface of low relief, but the character of the sediments contradicts this in a measure, for streams of considerable gradient must have existed in order to have transported the coarse sediments characterizing these strata. This apparent conflict may possibly be reconciled upon the assumption of a rather narrow coastal plain, adjacent to a mountainous country of considerable relief. If no land existed west of this shore-line, as seems probable, the physical environment of this region differed considerably from that of the present Sacramento Valley region.

The Upper Cretaceous beds of northern California were deposited in an inland sea protected from the open ocean by an archipelago, occupying the region of the present Siskiyou Mountains and the northern end of the Coast Ranges. Regarding this Diller and Stanton say

The attenuation of the Shasta-Chico Series westward from the Sacramento Valley and the overlapping of the newer beds upon older crystalline rocks of the Coast Range shows that the Coast Range was formed before the deposition of the Shasta-Chico series, and probably at the close of the Jurassic when the Mariposa beds were upturned.²⁹

Such a distribution of land might have had a marked effect upon the local oceanic currents, thereby producing temperature differences sufficiently great to account in part for the faunal dissimilarities noted above. Such a factor accompanied by others of lesser rank, concerning which but little is as yet known, is perhaps of sufficient importance to make it unnecessary to consider that the faunal peculiarities of the Santa Ana Mountains and northern California basins of deposition are due solely to different faunal stages.

RELATION TO FOREIGN CRETACEOUS FAUNAS

Various writers, including Gabb, White, Smith, Stanton, Hamilton, Whiteaves, and Anderson, have expressed opinions regarding the equivalents of the Chico group. This problem is complicated; therefore, only a few of the more recent, views upon this subject will be considered in this discussion.

Anderson, following in part the conclusions of Gabb and Whiteaves, considered that "the Chico, the Nanaimo, and the Phoenix and

²⁹ Diller, J. S., and Stanton, T. W., *op. cit.*, p. 464, 1894.

Henley beds may be shown to be homotaxially equivalent, and equivalent also to the beds of the Colorado group in the interior basin."³⁰

Anderson gives parallel lists of identical or closely related species found in the Chico and the Island of Ezo. His view of the relationships of the Chico to the European Cretaceous is best expressed in his own words:

On the whole, however, the strongest affinities are undoubtedly with the Turonian; and if one remembers the great stratigraphical range of some of the species of the Sacramento Valley, it does not seem remarkable that Cenomanian or even Gault types are found occasionally in the Chico.³¹

A correlation table shows that Anderson considered the Chico as including the Arrialon, Trichinopoli and a part of the Ootatoor groups of Southern India.³²

Stanton³³ takes issue with Anderson regarding the geographic relation of this western fauna to that of the interior basin.

Whiteaves and F. M. Anderson have argued for a connection during Chico time between the Pacific and interior seas, but the evidence brought forward in support of this view is based upon types that have a world-wide distribution and on those that are only similar, not specifically identical. In my opinion direct connection has not been proved.

Stanton believes, however, that the Chico began a little earlier than the Colorado group, including all of the Colorado and continuing a little longer than that group.

These citations are sufficient to indicate the major problems involved in the correlation of the Chico with beds outside of the Pacific Coast region. Further discussion of this problem will be considered in a future paper.

AGE

The Cretaceous beds of the Santa Ana Mountains yield a fauna that is more closely related to that from Chico Creek than to the fauna from the Horsetown beds. The relationships of these faunas are shown in the following table, in which there is indicated the number of species from the southern fauna common to these northern faunas as defined above.

³⁰ Anderson, F. M., Cretaceous Deposits of the Pacific Coast, Proc. Calif. Acad. Sci., Third Series, Geol., vol. 2, p. 57, 1902.

³¹ *Op. cit.*, p. 62.

³² *Op. cit.*, p. 62.

³³ Stanton, T. W., Later Mesozoic Invertebrate Faunas, in Outlines of Geologic History, Willis and Salisbury, p. 190, 1910.

TABLE REPRESENTING NUMBER OF SPECIES FROM CRETACEOUS OF SANTA ANA
MOUNTAINS KNOWN ALSO IN HORSETOWN AND CHICO

	Horsetown	Chico Creek
Number of species of Pelecypoda	4	19
Number of species of Gastropoda	0	5
Number of species of Cephalopoda	?	1
Total number of species in common	4	25
Per cent of species in common	5	31

The small percentage of typical Chico species represented in the southern fauna is due in part to the fact that the fauna from the *Actaeonella oviformis* zone is undoubtedly older than any horizon thus far reported from Chico Creek. This lowermost fauna is more closely related to the fauna from the beds immediately overlying the Horsetown group in Shasta and Tehama counties than to the type Chico. If the term Chico is made to include the known Cretaceous faunas of California that are younger than the Horsetown fauna as previously defined in this paper, the fauna from the Santa Ana Mountains may be properly designated as Chico. Such a procedure does not conflict with the generally accepted, though rather vague definition of the Chico. It thus appears that the type Chico in the restricted sense represents, as was pointed out by Anderson, but a portion of the Upper Cretaceous column of California.

SUMMARY

The Cretaceous strata of the Santa Ana Mountains are divisible into at least two groups. The lowermost one, consisting of about two hundred feet of red, non-fossiliferous conglomerates and sandstones, is here designated as the Trabuco formation. Conformably overlying these beds is a series of conglomerates, sandstones, and shales aggregating about two thousand feet in thickness, which have yielded a rich invertebrate fauna.

The Cretaceous fauna from the Santa Ana Mountains has certain affinities with that of the uppermost Horsetown beds but is much more closely related to the fauna from the Chico of Chico Creek. The small per cent of typical Chico species represented in the southern fauna is due in part to the fact that the fauna from the lowermost beds of the Santa Ana Mountains is undoubtedly older than any fauna thus far reported from Chico Creek, and also due in part to environmental differences resulting from the distribution of land on this Coast during the Upper Cretaceous.

Three faunal zones have been recognized in the Cretaceous of the Santa Ana Mountains. The lowermost, the *Actaeonella oviformis* zone, yields a large fauna which is older than that from the type Chico on Chico Creek, but younger than that of the uppermost Horsetown. The second, or *Turritella pescaderoensis* zone, possibly represents a part of the Chico known at Chico Creek; while the uppermost, the *Tellina ooides* zone, yields a fauna that is certainly included in the typical Chico.

Transmitted April 9, 1915.



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TERTIARY VERTEBRATE FAUNA FROM THE
CEDAR MOUNTAIN REGION OF
WESTERN NEVADA

BY

JOHN C. MERRIAM

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INTRODUCTION

In a study of the Tertiary faunas of the Great Basin province, now being carried on by the Department of Palaeontology of the University of California, one of the most fruitful investigations has been that comprising the exploration of the Cedar Mountain region of western Nevada. This area was visited by Charles L. Baker and John P. Buwalda in the summer of 1912 in the hope of finding a Tertiary mammalian fauna in deposits situated between the occurrences of Tertiary beds at Virgin Valley and Thousand Creek on the northern border of Nevada, and those of the Barstow and Ricardo areas of the Mohave Desert to the south.

Information regarding the occurrence of fossil remains in the area visited by Baker and Buwalda had previously been received through the courtesy of Mr. T. Holman Buck of Mina, Nevada, and through Professor George J. Young of the University of Nevada. Mr. Buck very kindly visited the localities with Baker and Buwalda, and was instrumental in securing and transporting to the railroad some of the most interesting material, notably the type specimen of a new and interesting anchitheriine horse. The area was visited by Dr. Buwalda in July, 1914, for the purpose of reviewing the work carried on in 1912.

The expedition in 1912 secured a significant collection, including a considerable variety of mammalian forms. Although the amount of material obtained is relatively small, the faunal representation is almost as large as that of the Barstow fauna, and in importance the area ranks with the Virgin Valley and Mohave localities.

In the preparation of the following report on the fauna of the Cedar Mountain region the writer has been especially indebted to Charles L. Baker and John P. Buwalda for their energetic prosecution of the field work through which the collection was obtained, and to Mr. Buck of Mina, Nevada, for information leading to location



Outline map of Tertiary provinces in the United States west of the Wasatch Range. CM, Cedar Mountain beds; E, Esmeralda beds; T, Truckee beds; MK, McKnight Miocene; V-T, Virgin Valley and Thousand Creek beds; Rt, Rattlesnake beds and Mascall; Rc, Ricardo beds; B, Barstow beds.

of the material and for subsequent assistance in packing and transporting the collection.

The drawings used in illustration of the Cedar Mountain fauna were all prepared by Mrs. Louise Nash.

OCCURRENCE

As represented on plate 8, the Cedar Mountain region lies a little more than fifty miles east of the western border of Nevada and near the middle of the state on a north-south line. It is east and southeast of Walker Lake, and northeast of the town of Mina.

The deposits in which the mammalian fauna occurs are spread over an area not less than fifteen miles in diameter, in Ione Valley and in Stewart Valley, but all seem to represent the same formation.

The geology of the Cedar Mountain deposits in which the mammalian fauna occurs has been admirably discussed by J. P. Buwalda.¹ The Tertiary sediments of the Cedar Mountain region are considered by Buwalda to represent a portion of the Esmeralda formation described by Turner² from the Silver Peak region immediately to the south.

The Tertiary beds representing the Esmeralda formation in the Cedar Mountain region consist of lacustral accumulations with intercalated beds of terrestrial origin. The formation here has a thickness of not less than one thousand feet.

The lacustral deposits consist in a large part of sandstones with shales, cemented tuffs, conglomerates, limestones, and cherts. The terrestrial beds comprise conglomerates, sandstones, and pumiceous tuffs. Within the lacustral beds at several localities are lithoid tufa domes similar to those occurring in the Pleistocene deposits of Lake Lahontan.

The Esmeralda formation of the Cedar Mountain region rests in very marked unconformity upon pre-Tertiary series which were greatly deformed and eroded before accumulation of the Esmeralda.

Between the Tertiary beds of the Cedar Mountain region and the older, much disturbed sediments are local rhyolitic and andesitic lavas markedly unconformable upon the older series, and also apparently not conformable with the Esmeralda. So far as observed the rhyolite

¹ Buwalda, J. P., Univ. Calif. Publ. Bull. Geol. vol. 8, pp. 335-363, pls. 32-38, 1914.

² Turner, H. W., Amer. Geol. vol. 25, p. 168, 1900. Also U. S. Geol. Surv. Twenty-first Annual Report, part 2, pp. 192-224, 1900; and Bull. Geol. Soc. Amer., vol. 20, p. 243, 1909.

flows antedate the andesites. Basaltic lavas are known to overlie the Esmeralda beds and seem to rest upon an eroded surface cut in the Esmeralda.

Judging from the amount of movement and erosion in beds above the pre-Esmeralda lavas as compared with that between the lavas and the older series, Buwalda judges that these igneous rocks largely represent lower or middle Miocene time. A post-lacustral andesite which has been deformed and much eroded is considered as probably Pliocene. A basalt resting in apparent unconformity upon the post-lacustral andesite at Table Mountain is considered as late Pliocene.

The Esmeralda formation of the Cedar Mountain region has been subjected to moderate deformation, six or seven low, open folds being noted by Buwalda in crossing Stewart Valley. Since the time of principal deformation the beds have suffered extensive erosion, which has been succeeded by a gentle warping presumed to have taken place in Pleistocene time.

In a sketch of the historical geology of Esmeralda County, Nevada, published in 1902, H. W. Turner³ refers to lake beds containing abundant fossils four miles west of Black Spring near the line between Esmeralda and Nye counties on the road between Sodaville and Cloverdale. A block containing molluscan and ostracod remains was obtained by Robert Stewart of Sodaville. This specimen was examined by J. C. Merriam who recognized the following molluscan forms:

<i>Sphaerium</i> , near <i>idahoense</i>	<i>Carinifex</i> , sp. <i>a</i>
<i>Melania</i> ?, sp.	<i>Carinifex</i> , sp. <i>b</i>

The *Sphaerium* and two *Carinifex* species resembled forms known from the Truckee beds of Fossil Hill in the Kawsah Mountains of Nevada. Two species of *Melania* are also known from the Fossil Hill beds. The fauna was considered by Merriam to resemble that of the Truckee, but evidence of similarity to the Esmeralda was not apparent.

From the block containing the molluscan shells a number of ostracods were obtained. These were referred to Dr. R. H. Chapman, who identified the forms as follows:

<i>Ilyocypris</i> , sp. nov., near <i>I. gibba</i>	<i>Candona</i> , sp. probably new
but distinct in important points	<i>Candona</i> , sp. probably new
<i>Candona</i> , sp. near <i>C. kingsleyi</i>	

Organic remains representing plants, molluscs, fishes, testudines, and mammals were obtained in the Cedar Mountain beds by Baker

³ Turner, H. W., Amer. Geol. vol. 29, p. 268, 1902.

and Buwalda. Remains of trees of considerable size were found in abundance in many localities. About one mile from Stewart Spring a silicified tree trunk not less than six feet in diameter is exposed.

Buwalda lists the following molluscan forms from the Cedar Mountain beds:

Heliosoma cordillerana Hannibal
Viviparus turneri Hannibal

Melania, near *sculptilis* Meek
Corneocyclas meeki Hannibal

The *Heliosma* and *Viviparus* are both abundant in the type section of the Esmeralda formation as well as in the Cedar Mountain beds. The *Melania*-like form is near a species described from the Truckee beds of the Kawsok Mountain.

Mammalian remains are known from many localities in the Cedar Mountain sediments of Ione Valley and Stewart Valley. They are most abundant in the sandstones and tuffs, but a few specimens have been discovered in angular terrestrial deposits. The material consists commonly of scattered bones, which often give evidence of weathering before burial. Connected parts of the type specimen of *Hypohippus* (*Drymohippus*) *nevadensis* were found in a slab of fine-grained ashly rock containing a large percentage of lime.

Conditions of occurrence indicate that the mammalian remains of the Esmeralda beds in the Cedar Mountain region were buried in part in shore deposits bordering fresh-water lakes, and in part were entombed in purely terrestrial beds. Remains of the smaller land mammals, including all of the rodents, are best known in association with those of fish in shore deposits of a lake. Bones of the larger land mammals occur to some extent in terrestrial beds.

RELATION OF ESMERALDA FORMATION TO CEDAR MOUNTAIN BEDS

In his study of the Cedar Mountain region Dr. Buwalda⁴ has shown that the extensive areas of Tertiary sediments examined in Stewart Valley and in Ione Valley can be traced stratigraphically into the Esmeralda formation described by H. W. Turner in the region of Silver Peak to the south. In order to assemble all information concerning the time relations of the Cedar Mountain fauna, it is therefore desirable to include in this paper a brief statement of the geologic relations of the Esmeralda formation at the type locality,

⁴ Buwalda, J. P., Univ. Calif. Publ. Bull. Dept. Geol. vol. 8, no. 19, 1914.

and a summary of available information regarding the fauna and flora of the Esmeralda.

In the type section of the Esmeralda, Turner describes the formation as consisting of light-colored marls, shales and sandstones, water-worn conglomerates, and Tertiary detrital-slope breccias. The formation was considered to have a thickness of at least 10,000 feet, and was presumed to represent in large part accumulation in a fresh or only slightly saline lake. Remains of plants, fresh-water molluscs, and fish indicated that the beds represented approximately Miocene age.

An interesting succession of lavas described by Turner from the Silver Peak region has definite relation to the Esmeralda sedimentary series and is therefore of unusual importance. The succession is as follows, reading from the latest members to the earliest ones referred to the Tertiary:

7. Dark, fine-grained olivine basalt, which may not be later than the Piper Peak flow.
6. Hypersthene basalt of Piper Peak.
5. Rhyolite-tuff interbedded with sandstones of the Esmeralda formation.
4. Andesite-breccia.
3. Rhyolite-tuff.
2. Andesite-breccia.
1. Older basalt associated with red basal conglomerate of the Esmeralda formation.

The plants of the Esmeralda were examined by F. H. Knowlton⁵ who listed the following forms:

Gleichenia? obscura Knowlton	Quercus argentum Knowlton
Dryopteris? gleichenoides Knowlton	Ficus lacustris Knowlton
Spathyema? nevadensis Knowlton	Chrysobalanus pollardiana Knowlton
Salix angusta? Al. Br.	Cercis? nevadensis Knowlton
Salix vacciniifolia Knowlton	Cinchonidium? turneri Knowlton
Salix, sp.	Rhus nevadensis Knowlton
Salix?, sp.	Indet.
Quercus turneri Knowlton	

Dr. Knowlton considered the flora of comparatively recent age with some species having closely corresponding forms as old as Eocene.

Tree trunks six to eight feet in diameter were found in the Esmeralda beds by Turner.

The fish remains were described by Dr. F. A. Lucas⁶ who referred them to a new species of the cyprinoid genus *Leuciscus*. This form,

⁵ Knowlton, F. H., U. S. Geol. Surv. 21st Ann. Rep. part II, pp. 209-224, 1900.

⁶ Lucas, F. A., U. S. Geol. Surv. 21st Ann. Rep. part II, p. 223, 1900.

Leuciscus turneri Lucas, is not certainly known from localities outside the Silver Peak region, but pharyngeal teeth of cyprinoid fishes are found in the Tertiary beds of the Cedar Mountain region. The fish remains suggested to Dr. Lucas comparatively late age of the Esmeralda, presumably Pliocene rather than Miocene.

Molluscan remains obtained by Turner were examined by J. C. Merriam⁷ who did not regard the species as definitely determinative. One of the species was recognized as near *Ancylus undulatus* Meek from the Truckee beds of the Kawsah Mountains of Nevada. Other species approached the characters of forms referred to the Eocene. The Esmeralda was considered as possibly early Miocene or late Eocene.

As nearly as can be determined from available evidence the Esmeralda formation, and with it the deposits of the Cedar Mountain region, should be correlated approximately with the Truckee beds described by King from the region of the Kawsah Mountains near the western border of Nevada some distance to the north. As has been shown by Buwalda, the molluscan forms of the Cedar Mountain beds are in part identical with those of the type section of the Esmeralda. There are also elements of similarity between the molluscan fauna of the Cedar Mountain beds and the small fauna listed by King from Truckee. Additional evidence of contemporaneity of the Truckee and Esmeralda is furnished by recent studies of Dr. F. H. Knowlton on a collection of plants obtained by the University of California from Truckee beds near Verdi, Nevada. Dr. Knowlton reports that the strongest affinity of the Verdi flora is with that of the Esmeralda formation. Of twelve species which Dr. Knowlton lists from the Verdi flora, six are apparently identical with or closely related to forms from the Esmeralda flora. The species common to the Truckee and the Esmeralda are the following:

<i>Salix angusta</i> Al. Braun	<i>Cercis?</i> <i>nevadensis?</i> Knowlton, smaller
<i>Salix</i> , sp.	<i>Ficus lacustris?</i> Knowlton, much smaller
<i>Rhus?</i> <i>nevadensis</i> Knowlton	<i>Chrysobalanus pollardiana</i> Knowlton

Of these the last four species are known only from the Esmeralda and Truckee beds.

⁷ Merriam, J. C. See Turner, H. W., U. S. Geol. Surv. 21st Ann. Rep. part II, p. 203, 1900

COMPOSITION OF CEDAR MOUNTAIN VERTEBRATE FAUNA

Pisces	Equidae
Salmon-like form	<i>Hypohippus</i> (<i>Drymohippus</i>) <i>nevadensis</i> Merriam
Cyprinoid form	<i>Hypohippus</i> , near <i>osborni</i> Gidley
Testudinata	<i>Merychippus</i> , sp.
Possibly <i>Clemmys</i>	<i>Protohippus</i> ?, sp.
Aves	Rhinocerotidae
<i>Nettion carolinense</i> (Gmelin)	<i>Aphelops</i> ?, sp. <i>A</i>
<i>Marila collaris</i> (Donovan)	<i>Aphelops</i> ?, sp. <i>B</i>
<i>Querquedula cyanoptera</i> (Vieillot)?	Proboscidea
Carnivora	<i>Tetrabelodon</i> , sp.
<i>Tephrocyon</i> , near <i>kelloggi</i> Merriam	Camelidae
Canid, or mustelid, small	<i>Procamelus</i> , near <i>gracilis</i> Leidy
Canid, near <i>Aelurodon</i> or <i>Tephrocyon</i>	<i>Pliauchenia</i> ?, sp.
Felid, large, probably <i>machaerodont</i>	Merycodontidae
Felid, small, near <i>Lynx</i>	<i>Merycodus furcatus</i> (Leidy)
<i>Bassariscus nevadensis</i> , n. sp.	<i>Merycodus</i> , near <i>necatus</i> Leidy
Rodentia	
<i>Dipoides</i> , n. sp.	
<i>Mylagaulus</i> , sp.	
<i>Aplodontia</i> ?, n. sp.	
<i>Lepus</i> , near <i>vetus</i> Kellogg	

RELATION OF THE FAUNA TO ITS ENVIRONMENT

A considerable part of the Cedar Mountain fauna comprises types which might inhabit a region of arid or semi-arid climate not greatly different from that of the Cedar Mountain area at the present day. This might be true of the canids, the rabbits, some of the horses, the camels, the merycodonts, and possibly the felids. Other forms, as *Bassariscus*, *Aplodontia*, and *Hypohippus*, are types that would naturally frequent a moist region or one well provided with trees or brush.

The remains of fish and of fresh-water shells obtained at certain localities in the Miocene of the Cedar Mountain region indicate the presence of fresh-water bodies probably of considerable size. Fossil wood representing trees of large size is common at a number of localities.

From consideration of all biological evidence available it appears that the environment in the Cedar Mountain region during the deposition of the mammal-bearing beds must have been noticeably different from that obtaining there at the present time. The presence of considerable bodies of fresh-water, the presence of abundant forest

trees, the existence of forest forms like *Bassariscus* and *Aplodontia*, and the relative importance of browsing types with rarity of grazing horses, all suggest a slightly more humid climate, with groves or brush areas such as may occur around the borders of the Great Valley of California at the present time.

STAGE OF EVOLUTION AND RELATIONSHIPS OF THE CEDAR MOUNTAIN FAUNA

Relation of the Cedar Mountain Fauna to the Tertiary Faunas of the Great Basin.—The faunal assemblage obtained in the Cedar Mountain region shows affinity with the Middle Miocene of Virgin Valley, but most nearly approaches the faunal stage of the Barstow Upper Miocene. It is distinctly older than the Ricardo, Thousand Creek, and Rattlesnake. Several differences between the Cedar Mountain and Barstow faunas may be due to geographic variation or may indicate that the Cedar Mountain beds cover a somewhat longer time range, including both older and younger beds than those from which collections have been obtained in the Barstow.

The Cedar Mountain fauna resembles that of the Middle Miocene Virgin Valley in the presence of a *Tephrocyon* near *kelloggi*, *Hypohippus*, *Merychippus*, rhinoceroses, and a *Meryodus* near *furcatus*. It differs from the Virgin Valley and Mascall in the presence of *Dipoides* and *Merycodus necatus*; in the more advanced stage of the horses; and so far as known in the quite advanced stage of the Aplodontia-like rodents, of the camels, and of the merycodont near *M. furcatus*.

Tephrocyon kelloggi, apparently represented in the Cedar Mountain by a portion of a lower carnassial, was described from the Virgin Valley. A similar form is, however, imperfectly known from the Thousand Creek Pliocene. The *Hypohippus* and *Merychippus* of Cedar Mountain are of more advanced types than those of Virgin Valley, and the *Merycodus* near *furcatus* is a larger, heavier form than that of Virgin Valley.

Dipoides is known in the Cedar Mountain beds but has not been found in the Middle Miocene. The Aplodontia-like form in the Cedar Mountain may be a more progressive type than the *Aplodontia* of Virgin Valley. Some of the fragmentary horse remains are much more specialized than any known from the Middle Miocene, and are even relatively advanced for the Barstow Upper Miocene. The total

assemblage of forms from the Cedar Mountain certainly seems more advanced than the Middle Miocene of the Great Basin, though it may approach it more closely than does the Barstow fauna.

Compared with the Upper Miocene fauna of the Barstow beds the Cedar Mountain fauna is distinguished especially by the absence of large aelurodons, and by the presence of rhinoceroses with *Merycodus furcatus* as the most common merycodont. Other differences, as the absence of *Merycochoerus* and *Dromomeryx* from the Cedar Mountain, and the absence of certain rodents as *Dipoides* from the Barstow, may be due to the chances of collecting.

Aside from the differences mentioned above, the Cedar Mountain and Barstow faunas have in general a similar aspect. The presence in the Cedar Mountain of a form of *Tephrocyon*; the occurrence in both faunas of a very progressive type of *Hypohippus*, an advanced *Merychippus*, and a protohippine form more specialized than typical *Merychippus*, indicate that the faunas are not widely separate in stage of development. It seems evident that the Cedar Mountain is nearer the Barstow than to any other faunal stage thus far known in the Great Basin, and is therefore probably of Upper Miocene age.

The presence of rhinoceroses and of *Merycodus furcatus* in the Cedar Mountain in the same association as in the Santa Fe Upper Miocene, whereas they are both absent from the Barstow, may be due to geographic variation or difference in environment. It is possibly due to slightly earlier stage of evolution of the Cedar Mountain fauna. The collections from the Barstow beds are the largest thus far brought together in the southwestern portion of the Great Basin, but as yet neither rhinoceroses nor *Merycodus furcatus* appears in the abundant material.

Compared with the Ricardo fauna, the mammals of the Cedar Mountain beds lack the advanced aelurodons, while the horses and camels are generally much more primitive. The presence of *Dipoides*, *Myiagaulus*, and one rather advanced horse in the Cedar Mountain beds would seem to show a relatively advanced stage; but *Dipoides* and *Myiagaulus* are both known in the Upper Miocene of America, although not as yet obtained in the Barstow, while the progressive horse may not be more specialized than one form in the Barstow beds.

Unless it be true that there is in the Cedar Mountain region a series of beds somewhat younger than those from which the principal fauna has been obtained, there is good reason for considering the fauna of these beds as considerably older than that of the Ricardo.

In comparison with the Thousand Creek and Rattlesnake Pliocene, the Cedar Mountain shows a wide difference in the horses and camels. The presence of *Hypohippus* and *Merychippus* with two species of *Merycodus* in the Cedar Mountain fauna indicates a much earlier stage than that of either the Thousand Creek or Rattlesnake, before the deposition of which these genera had disappeared.

TABLE ILLUSTRATING RELATIVE AGE OF THE CEDAR MOUNTAIN FAUNA COMPARED WITH OTHER FAUNAS OF THE GREAT BASIN PROVINCE

Time scale		Columbia and Middle Basin areas	Mohave area
Pliocene	Upper	Thousand Creek Rattlesnake	Ricardo
	Middle		
	Lower		
Miocene	Upper	Cedar Mountain Mascall	Barstow
	Middle		
	Lower	Columbia Lava	

Relation of Cedar Mountain Fauna to that of the American Tertiary East of the Great Basin.—The age of the Cedar Mountain fauna is best determined when this assemblage is considered in conjunction with other like faunas of the Great Basin region. Considering the similarity of this fauna to that of the Barstow beds, and the relation of the latter to the Upper Miocene Santa Fe fauna of northern New Mexico, there can be little doubt of the relation of the Cedar Mountain to the Upper Miocene.

Compared directly with the Santa Fe fauna, the Cedar Mountain mammals in some respects show a closer resemblance than do those of the Barstow. While the large aelurodons of the Santa Fe are not as yet known in the Cedar Mountain, there is a noticeable similarity in the camels, in the merycodonts, and in the presence of rhinoceroses, the last group being absent from the Barstow.

The Cedar Mountain fauna resembles that of the Upper Miocene or Lower Pliocene Republican River beds of the northwestern Kansas to a considerable extent, but seems less advanced in the canids, which are exclusively large specialized forms at Republican River. The Snake Creek fauna of western Nebraska also shows an interesting

similarity in the presence of *Tephrocyon*, a *Bassariscus*-like form, *Dipoides*, *Mylogaulus*, rhinoceroses, merycodonts, advanced camels, *Hypohippus* of an advanced stage, and *Merychippus*. The presence of numerous advanced horses of the *Neohipparion*, *Protohippus*, and *Pliohippus* types, with the introduction of true antelopes in *Neotragocerus*, indicates that the Snake Creek is younger than the Cedar Mountain, but the difference is evidently not measured by the lapse of more than half of a geological period.

On the whole there seems good reason for considering the Cedar Mountain fauna as near the Barstow and the Santa Fe in stage, and somewhat older than the Republican River and Snake Creek.

DESCRIPTION OF THE FAUNA

PISCES

A considerable number of fragmentary fish remains consisting of isolated vertebrate and parts of head bones were found at several localities. They include at least two forms, one near the salmon and the other too imperfect for determination. Professor J. O. Snyder of Stanford University, who examined the collection of fish remains from the Cedar Mountain beds writes concerning them as follows:

"I am returning the fossil fish remains today and I am unable to say anything further about them than that they appear to belong to some salmon-like form and are certainly not members of other families now living in the Great Basin. There may be more than one species represented. Dr. Jordan and others here could offer nothing more in way of suggestion."

TESTUDINATA

A few fragments of plates found in the deposits at locality 2027 in association with fish remains and with fresh-water gastropods may represent a type near *Clemmys*. The material is too imperfect for satisfactory identification. The form represented by the material may be a fresh-water type. No remains of land tortoises such as appear in the Barstow and Ricardo faunas are as yet certainly known from the Cedar Mountain beds.

AVES

A few fragmentary bird remains obtained in the Cedar Mountain region by Baker and Buwalda are interesting as representing some of the very few avian remains known from the West-American middle Tertiary.

Dr. L. H. Miller has kindly examined the material available and reports upon it as follows:

"Professor J. C. Merriam of the University of California has recently placed in my hands a small collection of bird remains collected in the Cedar Mountain beds of Western Nevada by Messrs. Baker and Buwalda in the summer of 1912."

"The material was fragmentary and somewhat worn, hence the identity in some cases is merely approximated. The specimens all represent anserines which at present inhabit fresh-water bodies or enclosed bodies of brackish or salt water. These bodies of water may be of most ephemeral nature and sometimes highly charged with alkaline salts. The presence of the species in the deposits of Nevada would therefore have little bearing on the question of climatic conditions during the deposition of these beds.

"The remains are listed as follows:

Distal end of humerus—*Nettion carolinense* (Gemlin)

Proximal end of humerus—Near *Marila collaris* (Donovan)

Distal end of tibia—*Marila collaris* (Donovan)

Proximal end of ulna—Near *Querquedula cyanoptera* (Vieillot)

Fragments of furcula—Indeterminate."

CARNIVORA

Carnivore remains are imperfectly represented in the collection from the Cedar Mountain region, but evidently include a considerable variety of forms. There are probably not less than six or seven species in the small amount of material available. Of these forms, three are canids, two felids, one possibly a mustelid, and one evidently a procyonid. The Carnivora do not evidence a very close relationship with those of any other fauna. One of the canids, *Tephrocyon* near *kelloggi*, is almost identical with a species described from the Virgin Valley Middle Miocene of northern Nevada. Another type is near the stage of development of the aelurodon of the late Miocene or early Pliocene.

TEPHROCYON, near KELLOGGI Merriam

A portion of a lower carnassial no. 19767 (figs. 2a and 2b) from Stewart Valley represents a species near or identical with *Tephrocyon kelloggi* of the Virgin Valley Miocene of northern Nevada. The fragment present is almost identical in form with the lower carnassial of the type specimen. Very slight differences are due mainly to the difference in stage of wear. The correspondence in form includes length of heel, size of metaconid, position and form of the small inner and outer tubercles between trigonid and talonid, the presence of a faint ridge of the cingulum on the outer side of the heel, and the development of a faint ridge on the outer portion of the posterior end of the heel. The measurements are nearly identical.

COMPARATIVE MEASUREMENTS

	No. 19767	Type T. kelloggi
M ₁ , anteroposterior diameter of heel on inner side,	4.3 mm.	4.1
M ₁ , greatest transverse diameter of heel	6.5	7.

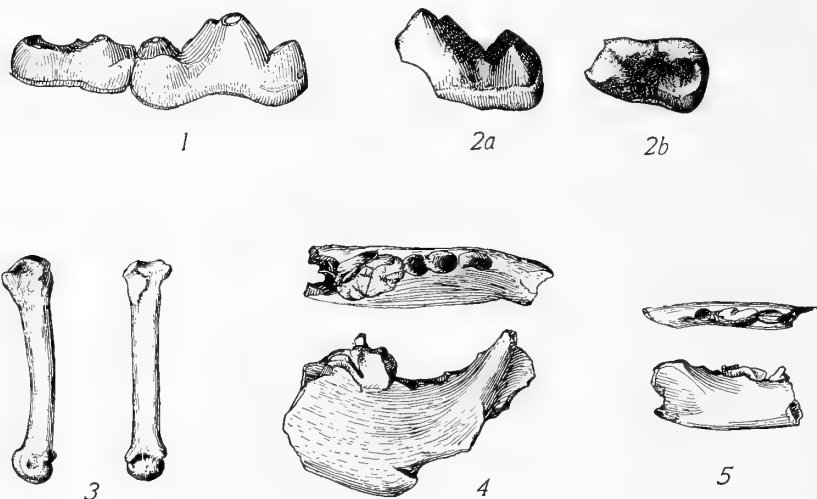


Fig. 1. *Tephrocyon kelloggi* Merriam. M₁ and M₂ of type specimen, $\times 1\frac{1}{2}$. Virgin Valley beds, Virgin Valley, Nevada.

Figs. 2a and 2b. *Tephrocyon*, near *kelloggi* Merriam. M₁, $\times 1\frac{1}{2}$. Cedar Mountain beds, Stewart Valley, Nevada. Fig. 2a, lateral view of M₁; fig. 2b, superior view of heel with protoconid and metaconid of M₁.

Fig. 3. Metacarpal III, possibly canid. No. 22289, $\times \frac{1}{2}$. Cedar Mountain beds, Stewart Valley, Nevada.

Fig. 4. *Aelurodon* or *Tephrocyon*, sp. Portion of mandible with broken carnassial, no. 19782, $\times \frac{1}{2}$. Cedar Mountain beds, twenty-eight miles northeast of Mina, Nevada.

Fig. 5. Mustelid?, indet. Portion of mandible, no. 19781, $\times \frac{1}{2}$. Cedar Mountain beds, Stewart Valley, Nevada.

CANID, AELURODON?, sp.

A portion of the mandible, no. 19782, (fig. 4), of a large canid represents a form near *Aelurodon*, or *Tephrocyon*. Of the Great Basin forms the species seems nearest to an *Aelurodon* from the Ricardo fauna.

CANID, sp.

Several astragali (no. 19780) represent a small canid.

MUSTELID?, sp

A portion of a small mandible no. 19781 (fig. 5) represents a Canis-like form with slender but thick jaws, small M₁, very small and one-rooted M₂, and no M₃. It presumably represents an unknown mustelid in the Cedar Mountain fauna.

FELID, sp. A.

A small phalangeal element (no. 19800, fig. 9), of a felid form from Stewart Valley, locality 2027, represents a cat of approximately the dimensions of the existing wildcat. It is uncertain whether it represented the feline or the machaerodine division of the family.

FELID, sp. B.

Phalangeal elements no. 19769 and 19700 (figs. 7 and 8) represent felids near the size of the puma. A slender, somewhat cat-like metapodial, no. 22289 (fig. 3), may not represent a felid form.

A humerus, no. 19765 (fig. 6) near the size of that in the Recent puma possibly belongs to one of the felid types mentioned above. The supinator ridge is much heavier than in the puma.

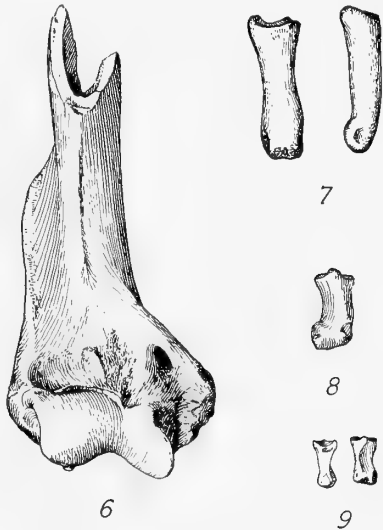


Fig. 6. Felid, indet. sp. B. Portion of humerus, no. 19765, $\times \frac{1}{2}$. Cedar Mountain beds, Stewart Valley, Nevada.

Figs. 7 and 8. Felid, indet. sp. Phalanges, nos. 19769 and 19700, $\times \frac{1}{2}$. Cedar Mountain beds, Lone Valley, Nevada.

Fig. 9. Felid, indet. sp. A. Phalanx, no. 19800, $\times \frac{1}{2}$. Cedar Mountain beds, Stewart Valley, Nevada.

MEASUREMENTS OF HUMERUS No. 19765

Greatest width across distal end	54. mm.
Least anteroposterior diameter of trochlea	17.3

BASSARISCUS NEVADENSIS, n. sp.

A portion of the mandible with the carnassial and premolars (fig. 10) from Stewart Valley, Nevada, locality 2027, represents a form almost indistinguishable from the Recent miners cat of California. The dimensions of the teeth are almost identical with those of two Recent

California specimens. In comparison with the modern *Bassariscus astuta* the fossil specimen (no. 19768) shows M_1 very slightly shorter anteroposteriorly, and the mandible somewhat higher and thicker. In the fossil form the posterior border of P_4 is less distinctly concave and the posterior cusp is relatively a little less prominent. The posteroexternal angle of the hypoconid of M_1 in the fossil specimen is more distinctly angular than in the Recent specimens of *B. astuta* examined.

A satisfactory comparison of the specimen from Stewart Valley with

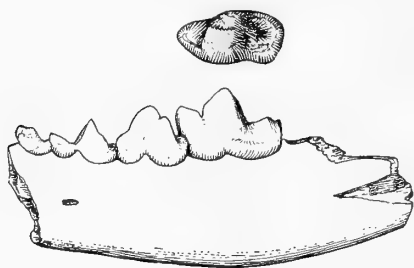


Fig. 10. *Bassariscus nevadensis*, n. sp. Lower jaw with dentition, no. 19768, $\times 2$. Cedar Mountain beds, Stewart Valley, Nevada.

Probassariscus antiquus from the Pliocene of Snake Creek, Nebraska, and the Miocene of Virgin Valley, is not possible, as M_2 is absent. It may be that this form possessed a paraconid on the tubercular molar as in *Probassariscus*, but this cannot be determined until more material is obtained. The mandible seems noticeably heavier in *Probassariscus*

than in specimen no. 19768, and there is a slight difference in the proportions of the lower carnassial.

There can be little doubt that the *Bassariscus* form from the Cedar Mountain region inhabited a territory that was fairly well watered and partly wooded. The climatic conditions must have been quite different from those obtaining in the Cedar Mountain region at the present time.

MEASUREMENTS

	Cedar Mt. specimen (a)	<i>B. astuta</i> Recent (b)	<i>B. astuta</i> (c) Recent	<i>P. antiquus</i> matthewi (d) Virgin Valley
P_3 , anteroposterior diameter	4.3 mm.	4.6	4.3	....
P_3 , transverse diameter	2.2	2.3	2.2	....
P_4 , anteroposterior diameter	4.9	5.	5	5.2
P_4 , transverse diameter	2.4	2.5	ap 2.4	2.7
M_1 , anteroposterior diameter	7.1	7.3	7.6	6.8
M_1 , transverse diameter across metaconid	3.8	3.9	3.8	3.8
M_1 , transverse diameter of heel	3.2	3.3	3.4	3.7
M_1 , anteroposterior diameter from base of protoconid to pos- terior end	2.4	2.4	2.4	2.8
Depth of lower jaw below M_1 ,	6.9	6.	6.7	7.8
(a) No. 19768	(b) No. 8800	(c) No. 8799	(d) No. 12539	
ap, approximate.				

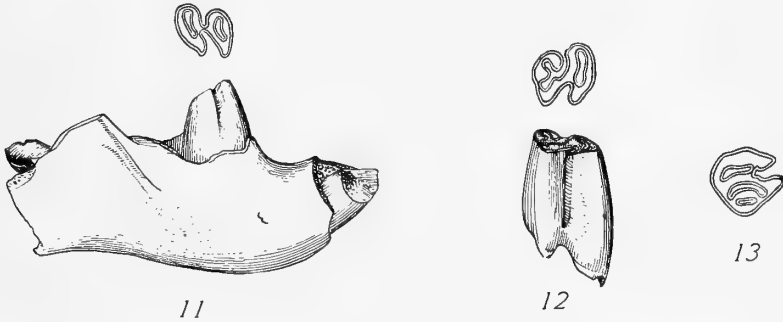
RODENTIA

DIPOIDES, near TORTUS (Leidy)

Several specimens from Stewart Valley (locality 2027) represent a form near this species. (See figs. 11 to 13.)

MEASUREMENTS

	No. 19802	D. tortus	D. curtus
Length of lower premolar series	17.5	19.5	14.5
P ₄ , greatest anteroposterior diameter	6.5	5.5	4.6
P ₄ , greatest transverse diameter	4.8	4.7	3.8
Depth of jaw below M ₂	9.5	14.	8.5



Figs. 11 to 13. *Dipoides*, near *tortus* (Leidy). Cedar Mountain beds, Stewart Valley, Nevada.

Fig. 11. Mandible with P₄, no. 19802, $\times 2$; fig. 12, P₄, no. 19804, $\times 2$; fig. 13, P₄, no. 19803, $\times 2$.

MYLAGAULUS?, sp.

A fragment of a large molar (no. 19801) from Stewart Valley (locality 2027) represents a mylagaulid form, but the tooth is too imperfect for specific determination. The specimen does not appear to differ distinctly from the fourth premolar of *Mylagaulus*, and may be referred provisionally to that genus.

APLODONTIA?, n. sp.

A single upper premolar, no. 19798 (fig. 14), from Stewart Valley, (locality 2027) represents a rodent evidently belonging in the group of the Aplodontidae, but not corresponding exactly to any form known to the writer. It shows resemblance both to *Meniscomys* and to *Aplodontia*, but does not duplicate the characters of either.

The crown of the tooth is worn down close to the large, very slightly divergent roots upon which it is supported. On the occlusal face there are at least four enamel lakes, which extend down almost to the lower end of the crown.

The form of the crown, taken with the depth and the tendency to cylindrical form of the enamel lakes, suggests that the normal unworn crown was short hypsodont.

The character of the tooth resembles in general that of *Aplodontia*, but differs in the shortness of the crown or in the depth of the enamel lakes, as also in the number of enamel lakes. In minor details of cross-section and in size, specimen 19798 would differ from any *Aplodontia* species known to the writer. In the Recent aplodontias, and in *Aplodontia alexandrae* of the Virgin Valley Middle Miocene, the

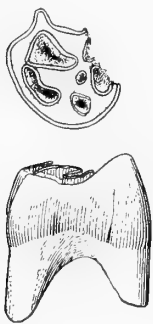


Fig. 14. *Aplodontia*?, n. sp. P^4 , anterior and occlusal views, no. 19798, $\times 4$. Cedar Mountain beds, Stewart Valley, Nevada.

crown of P^4 is long hypsodont, and the bottoms of the enamel valleys at the top of the crown disappear in early wear. In specimen 19798, the enamel valleys reach the lower end of the crown. Either the tooth was much shorter than in true *Aplodontia* or the enamel valleys were deeper.

On specimen 19798, there are four enamel lakes shown on the occlusal surface. Two are on the outer half of the surface, and two on the inner half. In a Recent *Aplodontia* a fourth upper premolar just about to come into use shows two external valleys, which apparently correspond to the enamel lakes seen in slightly worn teeth. A very shallow valley runs transversely over the tooth from the mesostyle to the inner border. In *Aplodontia alexandrae* an unworn P^4 shows a form similar in general to that of the Recent species, with the exception that the valley extending across the tooth from the mesostyle to the inner border is divided into outer and inner depressions separated by a wall. The outer of these two valleys is apparently deep, the inner valley is relatively shallow. A somewhat worn specimen of *Aplodontia alexandrae* shows on P^4 three enamel lakes which apparently correspond to the anteroexternal, posteroexternal and internal valleys. Three of the enamel lakes of specimen 19798 correspond approximately to the three seen in P^4 of *Aplodontia alexandrae*. The anterior and posterior lakes apparently correspond to the large lakes in Recent *Aplodontia*. The anterointernal lake seems to correspond to the anterointernal lake of worn teeth of *A. alexandrae*, or to the large shallow valley in the unworn specimen. Two very small canals in specimen 19798 may represent the middle outer valley next the mesostyle in *A. alexandrae*, though this must remain doubtful. The relation of the posterointernal lake of specimen 19798 to the valleys of *A. alexandrae* is doubtful. This lake occupies the position of a posterointernal valley in *Meniscomys*, which is presumed to be the ancestor of *Aplodontia*.

The writer considered the possibility that no. 19798 represents a milk premolar of a form like the Recent *Aplodontia*, and was fortunate in finding in the California Museum of Vertebrate Zoology a specimen with Dpm⁴ well preserved. Dpm⁴ of the Recent *Aplodontia* resembles specimen 19798 in the reaching down of the enamel valleys almost to the bottom of the relatively short crown, but the number of the enamel lakes does not correspond to that in no. 19798, and the roots of Dpm⁴ of the Recent form are much more divergent than in the fossil specimen. Divergence of the roots seems to be a necessary character in the Dpm⁴ in order to permit P⁴ to come down between the roots.

Though specimen 19798 is evidently nearest to *Aplodontia*, it shows an interesting resemblance to *Meniscomys*. In *Meniscomys* there are four valleys which are more pronounced than any other features of the occlusal surface, and a slight elongation of the crown with deepening of the valleys might produce in wear a section quite similar to that in specimen 19798.

The less rounded anterior side of the tooth in no. 19798 is more as in *Meniscomys*, as are the short crown and the non-divergent roots.

The exact relationships of this form are uncertain, more than that it quite certainly belongs with the Aplodontidae. It apparently lies between *Aplodontia* and *Meniscomys*, but is much nearer *Aplodontia*. Unless the specimen should be found to represent Dpm⁴ of an unknown species related to *Aplodontia alexandrae*, it probably pertains to a genus intermediate between *Meniscomys* and *Aplodontia*.

MEASUREMENTS

	No. 19798	<i>Aplodontia</i> <i>rufa</i>	<i>Aplodontia</i> <i>alexandrae</i>
P ⁴ , greatest anteroposterior diameter	ap 4.2 mm.	5	3.5
P ⁴ , greatest transverse diameter	3.9	5	4.
P ⁴ , height of portion of crown remaining	2.8		

ap, approximate.

LEPUS, near VETUS Kellogg

Two teeth from the collection at Stewart Valley, locality 2027, represent a leporid form which is near *Lepus vetus*, found in the Virgin Valley Miocene and Thousand Creek Pliocene of Nevada, but is probably specifically different from that form.

The teeth examined are slightly curved. The convex inner face shows a deep fold, the borders of which exhibit numerous secondary

plications (fig. 15). The anterior and inner faces are enamel-covered; the outer face and a portion of the anterior one are naked. The enamel of the inner face is covered with a layer of cement filling the fold on this side. The outer face is beveled obliquely. The beveled surface is faintly grooved longitudinally.



Fig. 15. *Lepus*, near *vetus* Kellogg. Cheek-tooth, no 19799, $\times 2$. Cedar Mountain beds, Stewart Valley Nevada.

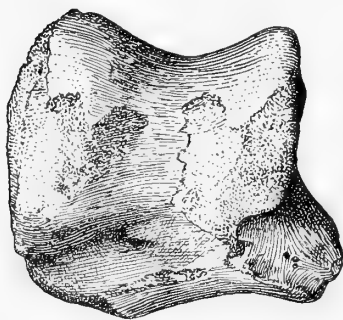
MEASUREMENTS OF No. 19799

Length of crown	9.7 mm.
Anteroposterior diameter	2.
Transverse diameter	3.7

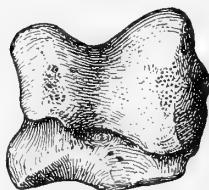
The form represented by the specimen measured is considerably smaller than the type of *Panolax sanctae-fidaei* from the Upper Miocene of New Mexico, and is quite certainly specifically distinct.

RHINOCEROTIDAE

Two forms known by astragali representing this group are found with the Cedar Mountain fauna, but the systematic position within the group is doubtful in both cases. In addition to these forms a number of tooth fragments and several foot bones (no. 22284) from near locality 2028 about four miles north of Stewart Spring represent a large rhinoceros with short feet approaching the *Teleoceras* type.



16



17



20

Fig. 16. *Aphelops?*, sp. A. Astragalus, no. 19824, $\times \frac{1}{2}$. Cedar Mountain beds, Stewart Valley, Nevada.

Fig. 17. *Aphelops?*, sp. B. Astragalus, no. 19822, $\times \frac{1}{2}$. Cedar Mountain beds, Nevada.

Fig. 20. *Hypohippus*, near *osborni* Gidley, $M_2^?$, occlusal view, no. 19763, natural size. Cedar Mountain beds, Stewart Valley, Nevada.

APHELOPS?, sp. A

A large astragalus, no. 19824 (fig. 16), from locality 2026, in Stewart Valley, represents a rhinoceros with a form of tarsus similar to that in *Aphelops*. This astragalus is near the size and form seen in a specimen from High Rock Cañon in northwestern Nevada.

APHELOPS?, sp. B

An astragalus, no. 19822 (fig. 17), with an anteroposterior diameter about one half that of no. 19824, seems to represent another rhinoceros possibly near the *Aphelops* type. This specimen is similar in size and form to a specimen 1201 from locality 871, presumably from the Upper John Day Oligocene of the eastern Oregon. The cuboid facet is a little large and is flatter at the lower end in the Cedar Mountain specimen. The inner facet for the astragalus is considerably smaller in the Cedar Mountain specimen.

EQUIDAE

Remains of horses are relatively rare in the Cedar Mountain beds, and only a very few teeth and isolated limb-bones have been obtained. Judging by the relative quantity of remains, the horse fauna seems to have been overshadowed in importance by the camels in this region during deposition of the Cedar Mountain beds.

The forms known thus far include *Hypohippus* (*Drymohippus*) *nevadensis*, a species near *Hypohippus osborni* but possibly identical with the first-mentioned form, a *Merychippus* species near the *M. calamarius* forms of the Barstow fauna, and a few fragments indicating the presence of a form more advanced than the common species of the Barstow. This last form may be comparable to the most advanced type of the Barstow resembling *Protohippus* or *Pliohippus* and rarely seen in that fauna.

It is perhaps significant that the browsing type, *Hypohippus* or *Drymohippus*, plays a relatively important part in the Cedar Mountain fauna as it is known at this time. If horses are relatively rare in Miocene deposits in which ungulates are fairly represented, and if the *Hypohippus* type represents a relatively large percentage of the horses present, one unavoidably considers the possible influence of environment in determining range and representation of the group. Absence of grazing horses, as *Merychippus*, and presence of browsing forms would be due to absence of grass or to predominance of brush.

The physical conditions under which the Cedar Mountain beds were deposited do not suggest a predominantly forested or brushy region, though both trees and brush were presumably present. It may be that grazing was relatively better elsewhere, and that *Merychippus* was abundant in regions not far distant.

HYPOHIPPIUS (DRYMOHIPPIUS) NEVADENSIS Merriam

Hypohippus (Drymohippus) nevadensis Merriam, Univ. Calif. Publ. Bull. Dept. Geol. vol. 7, p. 420, 1913.

Type specimen no. 21056, University of California Collections in Vertebrate Palaeontology. From the Cedar Mountain beds, in Stewart Valley, twenty-four miles northeast of Mina, Nevada.

Characters much as in *Hypohippus*, but metaloph of milk molars not connected with ectoloph.

Type specimen a small portion of the skull with three milk molars, portions of all four limbs, and a number of scattered fragments of other skeletal parts.

Skull and Dentition.—All that remains of the skull consists of a portion of the lower region of the cranium. The part of the cranium present exhibits little of significance.

The dentition of the type skull shows three well-preserved cheek-teeth. The incisors are not present. The cheek-teeth represent the milk dentition with Dm^4 just coming into function. The teeth rep-

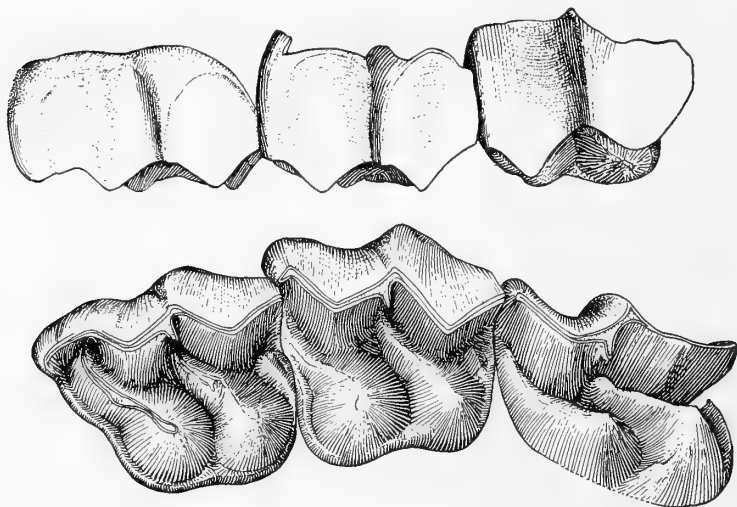


Fig. 18. *Hypohippus (Drymohippus) nevadensis* Merriam. Upper milk molars, outer and occlusal views, no. 21056, natural size. Cedar Mountain beds, Nevada.

resent an animal larger than any of the known forms of *Hypohippus*, but approaching in size *Hypohippus affinis*, the largest described species. They are absolutely larger than the permanent premolars of *H. osborni*, and larger than the milk molars of the type specimen of *H. affinis*. The excess in dimensions is evident in both the antero-posterior and transverse diameters.

In form and pattern the milk molars resemble in general the permanent dentition of *Hypohippus osborni*.

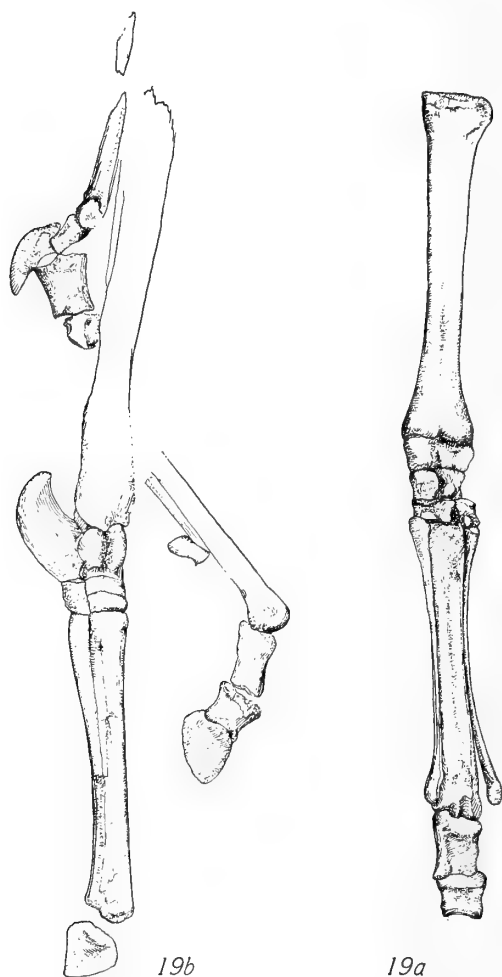
The principal difference between the Nevada specimen, no. 21056, and *Hypohippus osborni* is found in the separation of the outer end of the metaloph from the ectoloph. In none of the milk molars of the Nevada specimen is the summit of the outer end of the metaloph connected with the ectoloph. In Dm^2 and Dm^3 the base of the metaloph scarcely reaches the base of the ectoloph. In each of these teeth there is a small transverse ridge or tubercle pointing inward from the ectoloph at the posterior end of the paracone crescent. This transverse prominence arising from the ectoloph extends inward near the outer end of the metaloph but fails to meet that ridge. The outer end of the metaloph tends to swing a little in front of the inner transverse prominence of the ectoloph.

The inner transverse prominences arising from the ectoloph attain their greatest elongation or height near the summit of the ectoloph, and rapidly diminish in height as they extend toward the base of the tooth. On Dm^4 the transverse prominence consists of two small tooth-like projections. On the longer or lower of these points the diameter, parallel with height of the tooth crown, is not more than twice the anteroposterior diameter. The second projection, situated farther toward the base of the ectoloph, is an exceedingly small tubercle. The smaller projection does not reach the bottom of the valley between the metaloph and the metacone crescent. On Dm^3 the inner transverse prominence of the ectoloph is very small, and is situated near the crest of the ectoloph. On Dm^2 the prominence is higher, but is reduced rapidly at the proximal end and does not connect with the metaloph.

The Nevada form seen in specimen 21056 represents a type with dentition in general close to that of *Hypohippus*, but distinguished especially by the less advanced stage of evolution of the metaloph in the temporary molars.

Limbs.—Portions of both the anterior and posterior limbs (fig. 19*a* and 19*b*) exhibit some of the essential characters. The general

structure and proportions of the parts of the extremities preserved are near those of *Hypohippus*. The lateral digits and their ungual phalanges are relatively large, and were evidently functional. The first and second phalanges of the median digit are relatively shorter



Figs. 19a and 19b. *Hypohippus* (*Drymohippus*) *nevadensis* Merriam, no. 21056 $\times \frac{1}{2}$. Cedar Mountain beds, Nevada.

Figs. 19a, anterior limb; 19b, posterior limb.

and wider than in the *Merychippus* forms of the Miocene. The ungual phalanx of the median digit is broad, and the lateral wings show a stage of development at least as advanced as in *Hypohippus*. Metacarpal three shows a distinctly oblique lateral facet for articulation

with the unciform. In metatarsal three there seems to be a very small and quite oblique facet for the cuboid. In general the limb structure resembles that of *Hypohippus*.

COMPARATIVE MEASUREMENTS OF DENTITION

	Milk dentition		Permanent dentition		
	H. nevadensis No. 21056	H. affinis Type specimen		H. osborni	H. equinus
Dm ² , anteroposterior diameter along outer border	33	mm.	P ²	27.3	25
Dm ² , greatest transverse diameter	29	.....	P ²	26	25
Dm ³ , anteroposterior diameter along outer border	31.8	.....	P ³	25.4	25
Dm ³ , anteroposterior diameter measured through protoconule and hypostyle	29	.....	P ³	24	22 <i>b</i>
Dm ³ , greatest transverse diameter	30.5	.....	P ³	30	27
Dm ⁴ , anteroposterior diameter along outer border	31.9 <i>ap.</i>	28.5 <i>ap.</i>	P ⁴	30	25
Dm ⁴ , anteroposterior diameter measured through protoconule and hypostyle .....	.....	26.7 <i>a</i>	P ⁴	25	22 <i>b</i>
Dm ⁴ , greatest transverse diameter	31.4	29	P ⁴	30	26

a, measurements from J. Leidy's figure of type specimen.
b, from W. B. Scott's figures of type specimen.
ap, approximate.

MEASUREMENTS OF LIMB ELEMENTS, No. 21056

Radius, greatest length of shaft	241	mm.
Radius, least width of shaft	25	
Metacarpal II, greatest length	190	
Metacarpal III, greatest length	192	
Metacarpal III, width of distal end, approximate	28.5	
Phalanx I, digit III of anterior extremity, greatest length	40	
Phalanx I, digit III of anterior extremity, greatest width	30	
Phalanx II, digit III of anterior extremity, greatest length.....	30	
Phalanx II, digit III of anterior extremity, greatest width.....	31	
Metatarsal III, greatest length	203	
Metatarsal IV, greatest width at proximal end	17	
Phalanx I, lateral digit (hind foot?) greatest length along superior side	23.5	
Phalanx III, lateral digit (hind foot?) length along superior side	35	

Relationships.—The form represented in specimen no. 21056, resembles *Hypohippus* in the characters of the limbs and in general form of the cheek-teeth. It differs from *Hypohippus* in the separation of metaloph and ectoloph in the milk dentition. It is uncertain whether the permanent dentition of this species is represented in any of the

collections from the Great Basin region. The total characters, so far as known, indicate that the species is much nearer to *Hypohippus* than to any other group, and excepting the separation of metaloph and ectoloph it is not clearly distinguished from that genus. The gap between this form and typical *Hypohippus* seems less than the spaces between other anchitheriine genera. The new subgenus, *Drymohippus*, proposed to include this form, bears the characters of *Hypohippus* excepting in the separation of metaloph and ectoloph in the milk dentition. Later investigations may add other distinctive characters.

HYPOHIPPIUS, near OSBORNII Gidley

A lower molar (no. 19763, fig. 20) from locality 2027 represents a species of *Hypohippus* near the form found in the Middle Miocene of Virgin Valley in northern Nevada. This species is apparently nearer to *Hypohippus osborni* than to *H. equinus* or to *H. affinis*. Specimen no. 19763 is almost identical in dimensions with the Virgin Valley form. The tooth resembles the Virgin Valley species in form excepting in the character of the entostylid, which is relatively very weak in no. 19763. It is not improbable that additional material may show that the Nevada species is distinct from those previously described from other regions.

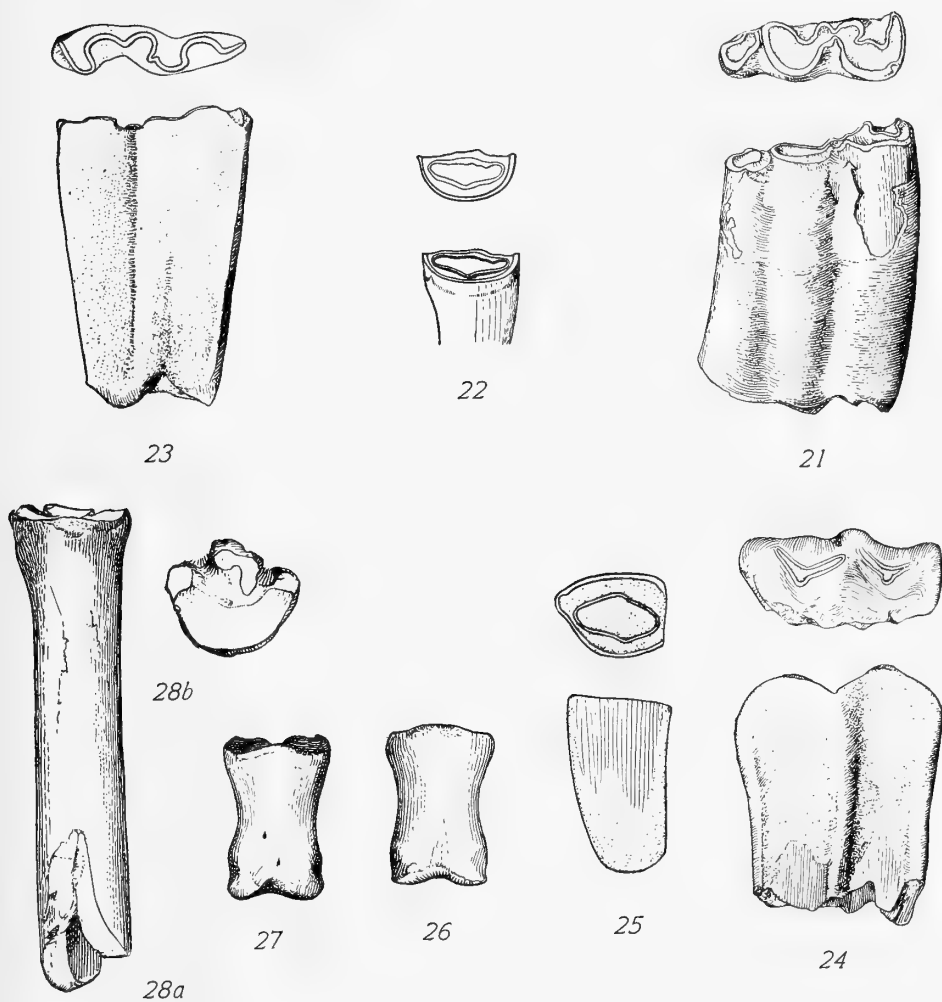
COMPARATIVE MEASUREMENTS

	No. 19763	No. 12587 Virgin Valley	Hypo- hippus osborni	H. equinus	H. affinis
M ₁ , anteroposterior diameter .....	.....	22. mm.	23.8	23.	28.5
M ₁ , transverse diameter .....	.....	16.	18.1	14.	20.
M ₂ , anteroposterior diameter ..	20.7?	21.	23.5	22.	.....
M ₂ , transverse diameter	14.3?	14.4	16.2	12.	.....

Two fragments of upper molars evidently represent *Hypohippus*.

MERYCHIPPUS, sp.

The proximal phalanges of the protohippine horse (figs. 26 and 27) from locality 2027 represent a type almost exactly similar to proximal phalanges of *Merychippus* from the Middle Miocene of Virgin Valley. They are also very close in form to phalanges of *Merychippus* from the Barstow Miocene. The Cedar Mountain specimens show a little less median constriction than the average specimens from the Barstow fauna, and in this respect are more like the Virgin Valley form.



Figs. 21 and 22. *Merychippus*, sp. Fig. 21, M_3 , external and occlusal views, no. 19825, natural size; fig. 22, incisor, inner and occlusal views, no. 22287, natural size. Cedar Mountain beds, Nevada.

Figs. 23 and 24. *Protohippus?*, sp. Fig. 23, inner portion of lower molar, no. 21483, natural size; fig. 24, outer portion of upper cheek-tooth, no. 22286, natural size. Cedar Mountain beds, Nevada.

Fig. 25. *Merychippus?* or *Hipparion?*, Incisor, external and occlusal views, no. 22285, natural size. Cedar Mountain beds, Ione Valley, Nevada.

Figs. 26 and 27. *Merychippus*, sp. Proximal phalangeal elements, $\times \frac{1}{2}$. Fig. 26, no. 19823; fig. 27, no. 22291. Cedar Mountain beds, Stewart Valley, Nevada.

Figs. 28a and 28b. *Merychippus?*, sp. Proximal end of metatarsal III, no. 21482, $\times \frac{1}{2}$. Cedar Mountain beds, Stewart Valley, Nevada.

A calcaneum (no. 21481) from locality 2027 represents a *Merychippus*-like species probably identical with that shown in the proximal phalanges.

The proximal end of a slender metatarsal (figs. 28a and 28b no. 21482) shows well-developed cuboid and mesocuneiform facets. It differs from *Merychippus*, and from the larger forms of the Ricardo referred to *Hipparion* and *Pliohippus*. The mesocuneiform facet is large, but is somewhat smaller than the cuboid facet. Both cuboid and mesocuneiform facets are nearly flat, or in the plane of the ectocuneiform facet. This specimen may represent *Hypohippus*. It differs from that genus in that the cuboid facet is nearly in the plane of the ectocuneiform facet, while in *Hypohippus*, as known to the writer, the cuboid facet slopes at an angle of near 45° from the plane of the ectocuneiform facet. In *Pliohippus* there is a distinct mesocuneiform facet, but the cuboid articulation is relatively larger.

A lower molar (no. 19825, fig. 21) from locality 2029 represents a protohippine horse of approximately the stage of evolution seen in one form of *Merychippus* near *calamarius* of the Barstow fauna. The crown is of moderate length and well cemented. The metaconid-metastylid column is short anteroposteriorly.

A fragment of an incisor (no. 22287, fig. 22) shows well-marked cupping and abundant cement in the pit. The stage of evolution of this tooth is approximately that of *M. calamarius*.

PROTOHIPPIUS?, sp.

Several fragments of upper cheek-teeth from localities 1979, 1984, 2029, and 2025 represent protohippine forms (fig. 24) at least as large as a very large *Merychippus* or *Protohippus* species of the Barstow fauna. These specimens may represent an advanced *Merychippus*, a *Protohippus*, or possibly a *Hipparion*. A rather narrow fossette of an upper cheek-tooth shows considerable crinkling of the enamel. It may represent a *Merychippus* or a *Hipparion*,

A large incisor (fig. 25) with deep cement-filled pit is larger than the incisors of any protohippine form known from the Barstow fauna. It corresponds more nearly to the stage of advance of a large *Hipparion* form of the Ricardo fauna.

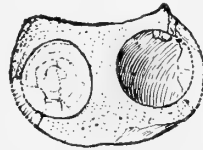
A fragment of a lower cheek-tooth (no. 21483, fig. 23) exceeds the dimensions of the average of the largest protohippine form of the Barstow fauna. The metaconid-metastylid column is short anteroposteriorly, and of the *Pliohippus* rather than of the *Hipparion* type.

The horses of the Cedar Mountain region possibly represent two horizons; one near that of the Barstow beds; the other possibly later and nearer the Ricardo stage, or possibly intermediate between Barstow and Ricardo.

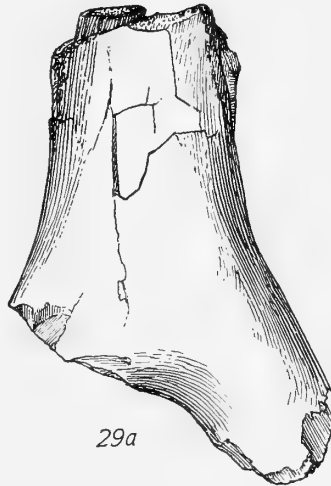
PROBOSCIDEA

TETRABELODON, sp.

Remains representing a large mastodon-like form are known from locality 1988. Several fragments of the lower jaw show a dentition including at least three cheek-teeth simultaneously in place in the mandible. Two large lower tusks are in place in the anteroposteriorly elongated symphyseal portion of the jaw (figs. 29a and 29b). A partial enamel covering is shown on the lower tusks. No specimens have been found in which the occlusal portion of the cheek-teeth is satisfactorily shown.



29b



29a

Figs. 29a and 29b. *Tetrabelodon*, sp. Symphyseal region of mandible, inferior view and cross-section, no. 22292, $\times \frac{1}{4}$. Fig. 29a, inferior view; fig. 29b, cross-section of distal end showing inferior incisors.

CAMELIDAE

PROCAMELUS, near GRACILIS Leidy

A specimen, no. 19820 (figs. 30a to 33) representing a small camel found by Baker and Buwalda, at locality 2028 in Stewart Valley, consists of a mandible with dentition, the anterior end of the cranium, a nearly complete anterior limb, six vertebrae and several other scattered fragments of the skeleton.

This species is near *Procamelus gracilis* and *P. occidentalis*, but is nearer the former in absolute size and in proportions of premolars. The dimensions of the Nevada form are close to those of Leidy's type and are near those of the specimen from New Mexico originally described by Cope as *P. occidentalis*,⁸ but later referred by him to *P. gracilis*.⁹ Cope's specimen is slightly smaller

⁸ Cope, E. D., U. S. Geol. Surv. west of 100th meridian, vol. 4, p. 329, 1877.

⁹ Cope, E. D., Geol. Surv. Texas, 3rd Ann. Rep. for 1891; footnote on p. 37.

and the metapodials seem a little more slender, but as nearly as can be determined by comparison of the upper jaw in Cope's specimen with the lower jaw from Nevada, the reduction of the premolars is nearly the same.

The reduction of the inferior premolars compared with the size of the molars, and especially with that of M_3 , is greater than in any of the other *Procamelus* forms known to the writer.

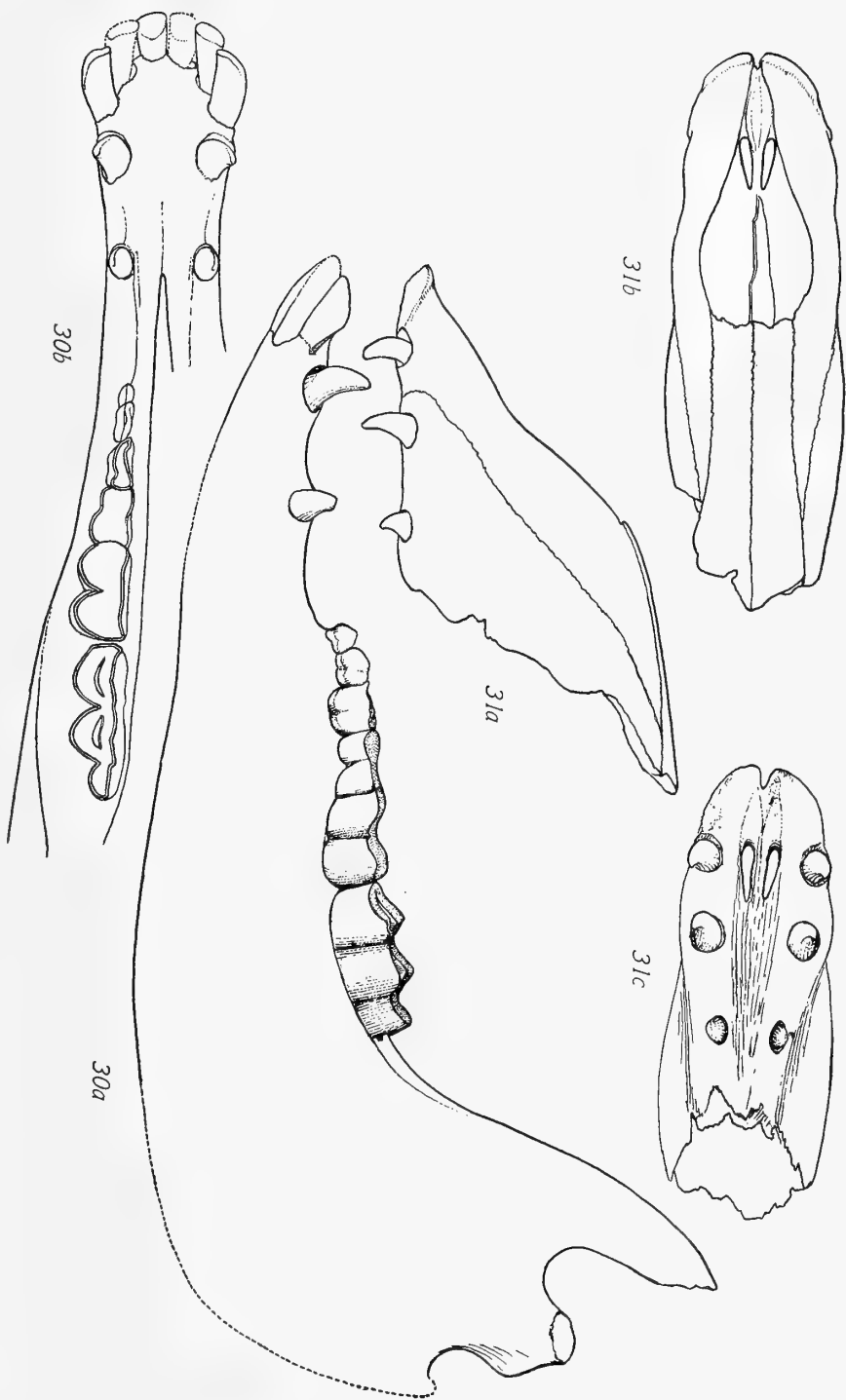
The Nevada form differs from *P. robustus* Leidy and *P. madisonianus* Douglass through its smaller size; from *P. lacustris* Douglass through its smaller premolars; from *P. elrodi* through its shorter molar-premolar series, and smaller premolars; from *P. fissidens* Cope through its relatively reduced premolars.

In the cranial fragment represented in specimen no. 19820 (figs. 31a to 31c), the rostrum is somewhat higher and in superior view apparently wider than in the skull of *P. gracilis* figured by Cope.¹⁰ The Nevada specimen has been crushed slightly and this may account to some extent for its apparently greater relative width. The narrow nasals are in broad contact with the premaxillaries anteriorly. In the Nevada specimen, the palatal surface between the anterior premolars is much narrower relatively than in the specimen described by Cope.

The mandible (figs. 30a and 30b) does not appear to differ in proportions from that of *P. occidentalis* and *P. robustus*.

In the inferior dentition every element is represented. The wide crown of I_3 is separated from the canine by a diastema less than one third the length of the diastema between the canine and P_1 . P_2 has a simple blade-like crown. The root is grooved laterally and may be completely divided at the lower end. P_3 has a blade-like crown with faint incipient folds of the enamel at the anterior and posterior ends of the inner side. The worn crowns of the fourth premolars show a posteroexternal and an anterointernal fold. The crowns are probably in too advanced a stage of wear to show the posterior fold. M_1 is much worn and shows no distinctive characters. In M_2 the posterior lobe is relatively wide transversely. M_3 is uncommonly long anteroposteriorly. Compared with other forms its anteroposterior diameter is very large in relation to the dimensions of the premolars. The posterior lobe of M_3 stands almost parallel with the plane of the first and second lobes, showing a scarcely perceptible bend outward. The medial wall of the posterior lobe is nearly even with the plane of

¹⁰ *Op. cit.*, pls. 76 and 77.

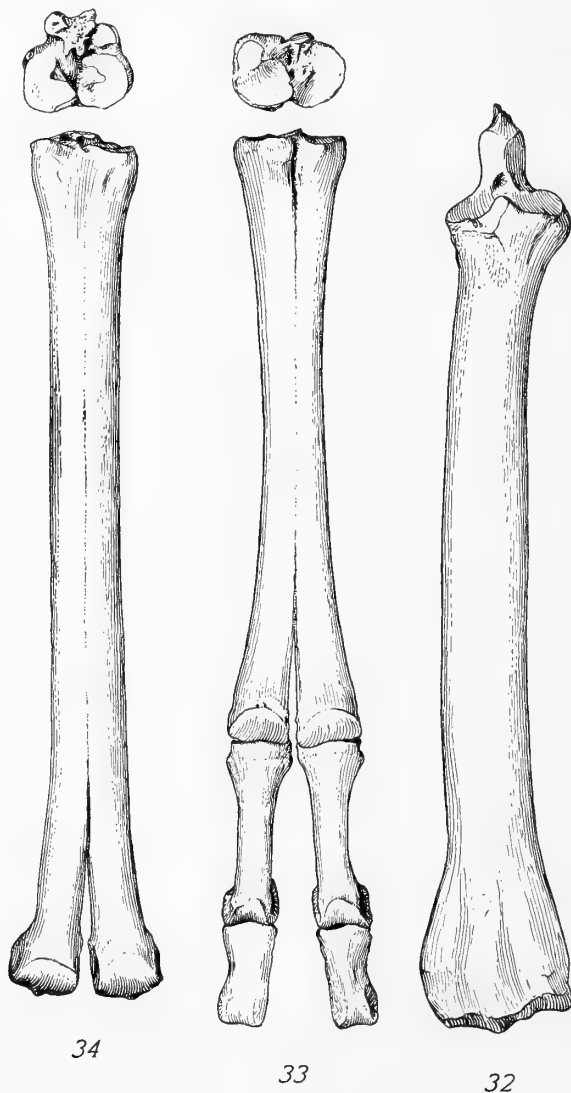


Figs. 30a to 31c. *Procamelus*, near *gracilis* Leidy. Mandible with a portion of the rostral region, no. 19820, $\times \frac{1}{2}$. Cedar Mountain beds, Stewart Valley, Nevada. Fig. 30a, mandible, lateral view; fig. 30b, mandible superior view; fig. 31a, rostral region, lateral view, showing premaxillary with a portion of the nasals and maxillary; fig. 31b, rostral region, superior view; fig. 31c, rostral region, palatal view.

the middle lobe, but is separated from it by a small, sharply-marked fold or jog of the inner wall.

Excepting I_3 , the canine, and P_1 the upper dentition is known only by fragments.

An anterior limb (figs. 32 and 33) lacking only the terminal phalanges and the proximal end of the humerus closely approaches the



Figs. 32 to 34. *Procamelus*, near *gracilis* Leidy. Cedar Mountain beds, Nevada.
Fig. 32. Epipodial segment, anterior limb, no. 19820, $\times \frac{1}{3}$.
Fig. 33. Metapodials and phalanges, anterior limb, no. 19820, $\times \frac{1}{3}$.
Fig. 34. Cannon bone, posterior limb, no. 22293, $\times \frac{1}{3}$.

characters shown in the limb of the specimen of *Procamelus gracilis* described by Cope from New Mexico. The metapodials of the Nevada specimen are about one tenth larger than in the New Mexico form, and also slightly heavier. The two elements of the cannon bone are completely fused, though the distal separation reaches considerably higher on the shaft than in the llama.

The epipodial segment of the limb does not differ noticeably from that of the New Mexico specimen. The ulna and radius are completely fused.

MEASUREMENTS						
	Nevada specimen No. 19820		<i>P. gracilis</i> Cope's New Mexico specimen	<i>P. occidentalis</i> Type specimen	<i>P. robustus</i> Type specimen	
Length, anterior side I ³ to posterior side P ¹	54.	mm.	44	.....	.....
Length, posterior side superior canine to an- terior side P ¹	20.5		16	.....	.....
Width between inner sides of third upper incisors	22.7		20	.....	.....
Width between inner sides of first upper pre- molars	12.4		16	.....	.....
Length, anterior side inferior canine to pos- terior side M ₃	178.		.....	.....	.....
Length, anterior side P ₂ to posterior side P ₄	29.		.....	42.2	48
Length, anterior side P ₂ to posterior side M ₃	111.		.....	.....	.....
Length, anterior side M ₁ to posterior side M ₃	81.2		.....	.....	.....
Height of mandible below anterior side of M ₃	50.7		.....	.....	60
Height of mandible below anterior side of M ₁	47.5		.....	.....	52.5
Anteroposterior diameter of symphysis	60.		.....	.....	.....
Inferior canine, greatest anteroposterior diameter	8.2		<i>P. gracilis</i> Type specimen	.....	.....
P ₁ , greatest anteroposterior diameter	8.5			.....	.....
P ₂ , greatest anteroposterior diameter	8.			8	13 15	
P ₃ , greatest anteroposterior diameter	11.9			10.2	14.7 17.3	
P ₄ , greatest anteroposterior diameter	14.8			12.5	16.4 20.3	
M ₁ , greatest anteroposterior diameter	16.6		.....	22	29.8
M ₂ , greatest anteroposterior diameter	25.		.....	28.5	33?
M ₂ , greatest transverse diameter of posterior lobe	16.2		<i>P. gracilis</i> Cope's New Mexico specimen	.....	.....
M ₃ , greatest anteroposterior diameter	40.			37	48	
Anterior cannon bone, greatest length	245.			222
Anterior cannon bone, greatest proximal width	43.			35.3
Anterior cannon bone, greatest distal width ...	51.5			42.6
Anterior cannon bone, least transverse diameter of shaft	23.5		20.4	.....	.....
Phalanx one, anterior extremity, greatest length	75.		65	.....	.....

A well-preserved atlas and a portion of an axis with specimen 19820 do not differ appreciably from those of Cope's New Mexico specimen excepting in their slightly larger size.

PLIAUCHENIA?, sp.

Astragali and phalanges (figs. 35, 37 and 40) of a large camel having at least twice the bulk of *Procamelus gracilis* are found in the Cedar Mountain fauna. These elements correspond approximately to foot-bones referred to the genus *Pliauchenia* in the fauna of the Barstow beds. Until material showing structure of dentition and limbs is adequately represented, it is useless to speculate as to the specific determination of the form represented by these specimens.

MERYCODONTIDAE

A small collection of the material including antlers, teeth, and a portion of a jaw from the Cedar Mountain region represents one or more species of *Merycodus*. One form seems identical with *M. furcatus*, another is indistinguishable from antlers which form a part of the series included in *M. necatus* from the Barstow beds.

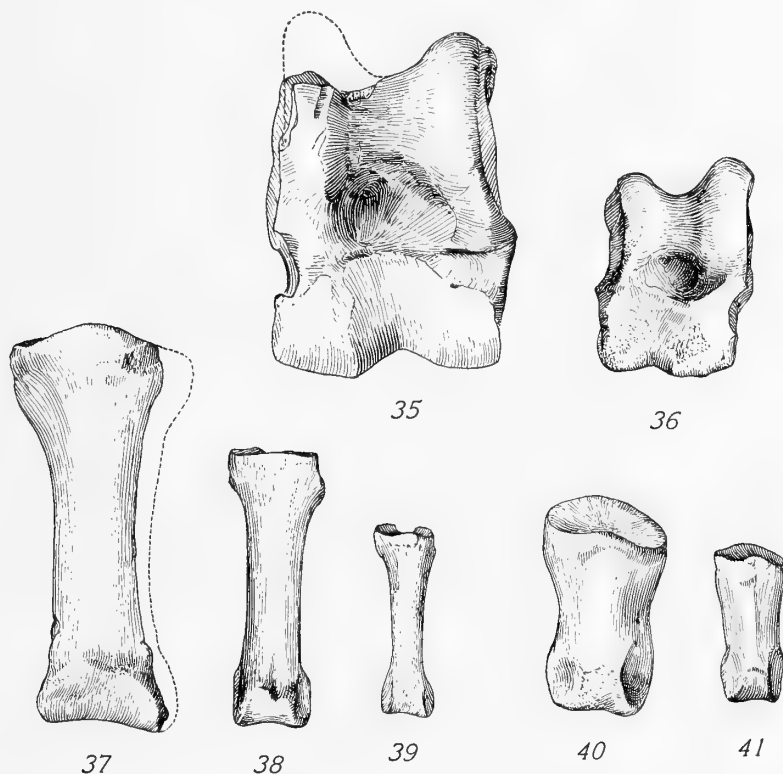
MERYCODUS FURCATUS (Leidy)

A nearly complete antler no. 21492 (fig. 44) from Ione Valley resembles *Merycodus furcatus* in the round, little-flattened beam with strongly-curved, slender tines.

A second specimen, no. 19807 (fig. 45) shows a long, slender beam with nearly circular cross-section. It is broken above and shows no tines. This form of antler is entirely unlike that of *Merycodus necatus*, but may appear in *M. furcatus*. The majority of the fragments of antlers found seem most nearly to approach the *M. furcatus* type.

A portion of a jaw, no. 19805 (fig. 46) found at the same locality with the slender antler no. 19807 shows the last two inferior premolars. A number of scattered teeth include M_2 and M_3 . The lower molars are strongly hypsodont. M_3 (fig. 48) shows a moderately developed third or posterior lobe. The premolars in no. 19805 are somewhat elongated, while the inner lateral grooves are short and deep. The outer posterior lateral groove is imperfectly marked, and in this respect these teeth seem less progressive than in the premolars from the

Barstow fauna referred to *M. necatus*. According to Cope's figures,¹¹ *M. furcatus* seems to be distinguished from *M. necatus* by narrower inferior premolars with less marked posteroexternal groove. These



Figs. 35-41 represent specimens from the Cedar Mountain beds in Nevada.

Fig. 35. *Pliauchenia*?, sp. Astragalus, no. 22294, $\times \frac{1}{2}$.

Fig. 36. *Procamelus*, sp. Astragalus, no. 22295, $\times \frac{1}{2}$.

Fig. 37. *Pliauchenia*?, sp. Proximal phalangeal element, no. 22302, superior view, $\times \frac{1}{2}$.

Figs. 38 and 39. *Procamelus*, two species? Proximal phalangeal elements, superior view. Fig. 38, no. 22296, $\times \frac{1}{2}$; fig. 39, no. 22297, $\times \frac{1}{2}$.

Fig. 40. *Pliauchenia*?, sp. Second phalangeal element, superior view, no. 22298, $\times \frac{1}{2}$.

Fig. 41. *Procamelus*, second phalangeal element, no. 22299, $\times \frac{1}{2}$.

teeth are in some respects like those of *Blastomeryx*, but the crowns are more hypsodont. From the character of this specimen and its association with molars and antlers of *Merycodus*, it is probably to be referred to that genus.

¹¹ Cope, E. D., U. S. Geol. Surv. West of 100th meridian, pl. 82, figs. 1a to 2b, 1877.

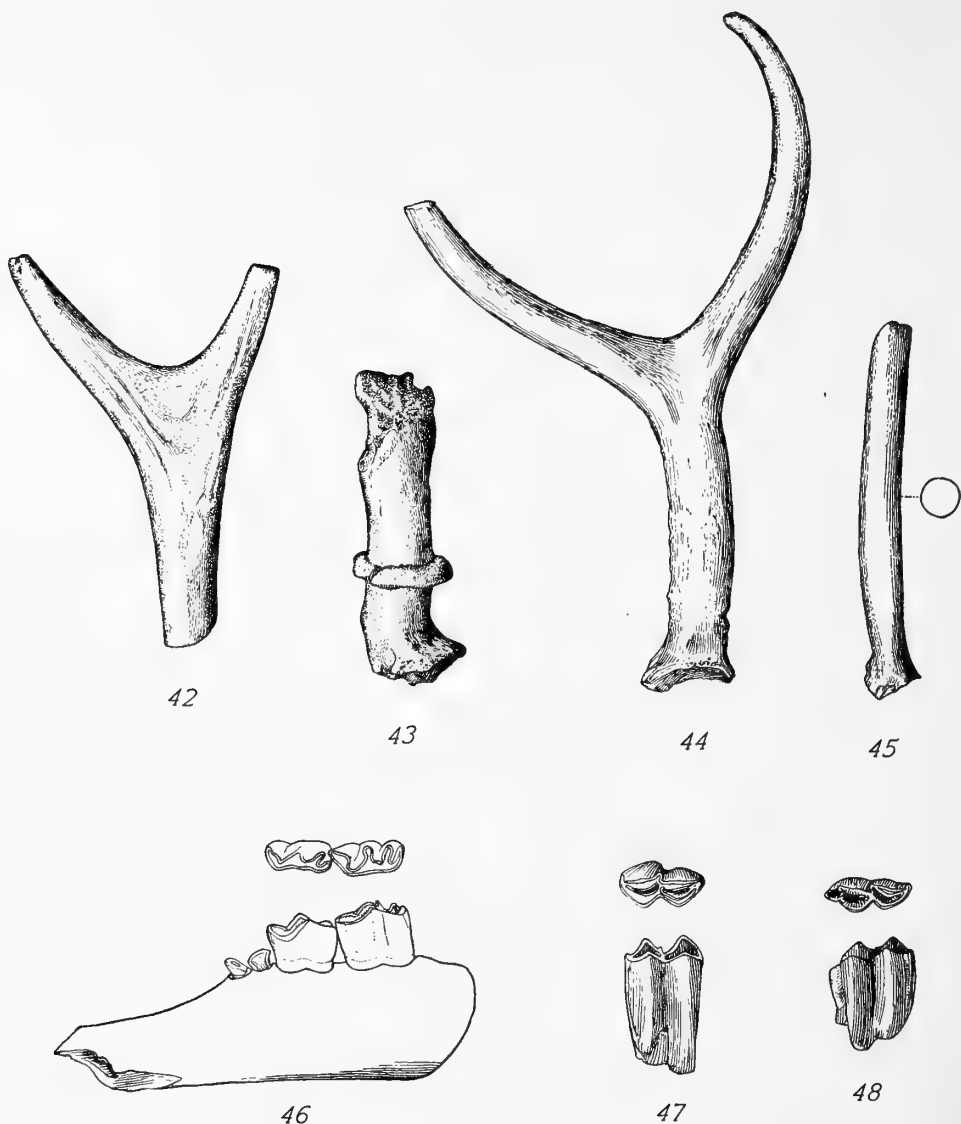


Fig 42. *Merycodus*, near *necatus* Leidy. Antler, no. 21493, $\times \frac{1}{2}$. Cedar Mountain beds, Ione Valley, Nevada.

Figs. 43 to 45. *Merycodus furcatus* (Leidy). Antlers, $\times \frac{1}{2}$. Cedar Mountain beds, Nevada. Fig. 43, no. 19806, Ione Valley; fig. 44, no. 21492, Ione Valley; fig. 45, no. 19807, Stewart Valley.

Figs. 46 to 48. *Merycodus*, sp. Cedar Mountain beds, Stewart Valley, Nevada. Fig. 46, lower jaw with P_2 to P_4 , no. 19805, $\times 1\frac{1}{2}$; fig. 47, M_2 , no. 22300, natural size, external and occlusal views; fig. 48, M_3 , no. 22301, external and occlusal views, natural size.

MERYCODUS, near NECATUS Leidy

A single antler no. 21493 (fig. 42) from Ione Valley shows a form not distinguishable from one phase of the series of antlers referred to *Merycodus necatus* in the Barstow fauna. The form of the antler is not greatly different from that in no. 21492 (fig. 44) referred to *M. furcatus*, but the beam is more strongly flattened and broadens more gradually above. The tines seem to have been relatively smaller, shorter, and less curved than in the other form. This specimen may represent only a form of the *M. furcatus* series, but must be recognized tentatively as like the form from the Barstow beds referred to *M. necatus*.

A calcaneum from locality 2022 in Ione Valley represents a *Merycodus* species.

DESCRIPTION OF COLLECTING LOCALITIES IN THE CEDAR MOUNTAIN REGION OF WESTERN NEVADA

Loc. 1969. South side of gulch in low bluffs just west of outcrop of plutonic rock, on south side of road $\frac{1}{8}$ mile east of point at which 5,800-foot contour crosses the direct road from Bell Spring to Black Spring. Basal beds. Tonopah Quadrangle.

Loc. 1970. Fifty feet stratigraphically above very fossiliferous shell beds on north side of shallow canyon, $\frac{1}{2}$ mile north of the direct road from Bell Spring to Black Spring. Elevation 6050 feet. Tonopah Quadrangle.

Loc. 1971. At 6250 feet elevation, 1 mile north of road intersection which intersection is 2 miles southeast of Bell Spring. Probably near base of lake beds series. Tonopah Quadrangle.

Loc. 1972. At 6075 feet elevation, $\frac{1}{2}$ mile northwest of point at which 6000-foot contour crosses the road between Bell Spring and Black Spring. Tonopah Quadrangle.

Loc. 1973. In first gulch north of direct road from Bell Spring to Black Spring. Between 5900 and 6000-foot contours, on a small hill in the middle of the gulch. Horizon not near base. Tonopah Quadrangle.

Loc. 1974. One-fourth mile northeast of loc. 1973. Tonopah Quadrangle.

Loc. 1975. At 5775-foot elevation, $\frac{1}{2}$ mile north of direct road from Bell Spring to Black Spring. Tonopah Quadrangle.

Loc. 1976. In a fine, light brown tuff 30 or 40 feet above the granite contact, at a point on the 6000-foot contour, about $1\frac{1}{2}$ miles north of the direct road from Bell Spring to Black Spring. Tonopah Quadrangle.

Loc. 1977. On the 6300-foot contour, about $\frac{1}{2}$ mile south of conspicuous, lava covered butte, which is $1\frac{1}{2}$ miles east of Bell Spring. Tonopah Quadrangle.

Loc. 1978. On the southern-most flanks of the Shoshone Mountains, about $\frac{1}{2}$ mile north of the road between Black Spring and Cloverdale and about 300 yards east of the road to Willow Springs near 5500-foot contour. Tonopah Quadrangle.

Loc. 1980. About $\frac{1}{2}$ mile north of loc. 1969, in a small side canyon 50 yards east of low cliffs in the first large canyon north of the direct road from Black Spring to Bell Spring. Tonopah Quadrangle.

Loc. 1982. Near the bottom of gulch $\frac{1}{2}$ mile north of highest butte of the Esmeralda beds in the middle of Stewart Valley, $\frac{1}{2}$ mile west of Finger Rock Wash, and about 2 miles west of Stewart Spring. Soft rusty-brown beds. Tonopah Quadrangle.

Loc. 1984. In Finger Rock Wash at elevation of 5550 feet. Tonopah Quadrangle.

Loc. 1985. About $\frac{1}{2}$ mile due west of loc. 1986, in the strata immediately above the gray tufaceous layer prominently exposed along the west side of the gulch. Tonopah Quadrangle.

Loc. 1986. Immediately south of the point at which the mapped road from Stewart Spring to Pactolus crosses the line between Nye County and Esmeralda County. Tonopah Quadrangle.

Loc. 1987. One-half mile southwest of the point at which 6000-foot contour crosses the line between Nye County and Esmeralda County, about 3 miles north of the Nevada Mine. Tonopah Quadrangle.

Loc. 1988. A point immediately west of the intersection of the 6000-foot contour and the line between Nye County and Esmeralda County, about 3 miles north of the Nevada Mine. Tonopah Quadrangle.

Loc. 1989. Three miles east of Table Mountain, immediately northwest of small hill west of road leading north to Stewart Spring, longitude $117^{\circ} 55'$ west, latitude $38^{\circ} 32'$ north. Tonopah Quadrangle.

Loc. 2021. On 5900-foot contour $2\frac{3}{4}$ miles due west of B. M. 5571, which B. M. is near Black Spring. Tonopah Quadrangle.

Loc. 2022. One-fourth mile southeast of loc. 2021. Tonopah Quadrangle.

Loc. 2023. One-half mile west of loc. 2021 and in the same gulch on the 6000-foot contour. Tonopah Quadrangle.

Loc. 2024. About $\frac{1}{4}$ mile due west of loc. 2021 on the south side of the same gulch. Tonopah Quadrangle.

Loc. 2025. About $\frac{3}{8}$ mile south of loc. 2021, near the 6000-foot contour. Tonopah Quadrangle.

Loc. 2026. About 2 miles south, 76° west, from the higher of two buttes situated in Stewart Valley, about $\frac{1}{2}$ to $\frac{3}{4}$ of a mile west of the point where Stewart Spring Gulch joins Finger Rock Wash. About 200 feet above the base of the series. Tonopah Quadrangle.

Loc. 2027. Gray beds in the forks of the mapped roads at Stewart Spring. Tonopah Quadrangle.

Loc. 2028. Along the road one mile west of loc. 1986. Tonopah Quadrangle.

Loc. 2029. One-half mile northeast of loc. 1986 in gulch cut into brown tuff. Tonopah Quadrangle.

Loc. 2030. About 2 miles west of the Nevada Mine and immediately south of the East West road at this point. Tonopah Quadrangle.

Loc. 2031. In limestone about $\frac{5}{8}$ mile southwest of the Nevada Mine, on a sharp jagged hill about 200 feet high, just west of the exposure of white igneous rock. Tonopah Quadrangle.

Loc. 2032. About $2\frac{1}{2}$ miles southwest of the Nevada Mine, at an elevation of 6300 feet. Tonopah Quadrangle.

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GEOLOGY

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Issued February 24, 1916

FAUNA FROM THE LOWER PLIOCENE AT
JACALITOS CREEK AND WALTHAM
CANYON, FRESNO COUNTY,
CALIFORNIA

BY

JORGEN O. NOMLAND

UNIVERSITY OF CALIFORNIA PRESS

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INTRODUCTION

On approaching the eastern foothills of the Diablo Range about seven miles southeast of Coalinga, California, the stratified deposits are found to consist chiefly of soft beds of the lower and middle Pliocene. These strata comprise several thousand feet of much folded and faulted sandstones and shales dipping away from the underlying Crétaceous and Tertiary. In the mapping of this district by the members of the United States Geological Survey the upper portion was

correlated with the Etchegoin formation north of Coalinga, while the lower part was given the formational name Jacalitos. This division was based chiefly on palaeontologic evidence, as the two formations wherever found in contact are apparently conformable. The fauna obtained from the Jacalitos was, however, small and the greater number of the species listed either new or of very long range. As a consequence the Jacalitos has been grouped with the underlying Santa Margarita formation by some California palaeontologists and geologists and with the overlying Etchegoin by others.

In the present paper a fauna of 82 species is listed. Although a number of the species have a long range and a few are new, yet the fauna seems large enough to fix the position of the beds of this lower horizon on Jacalitos Creek and Waltham Creek more definitely in the stratigraphic column than has been possible heretofore.

HISTORICAL REVIEW

The Neocene in this region was first described in a publication by F. M. Anderson,¹ who considered what has later been mapped as Jacalitos and Etchegoin equivalent for the most part to the several lithological units grouped in what were called the Coalinga Beds, north of the town of Coalinga. In a later paper the same author² restricted his definition of the Coalinga Beds "to the lower portion of a series which is unconformably related to the older members of the Miocene." At what locality this occurs or to what unconformity this has reference is not known to the writer.

A report by Ralph Arnold³ on the palaeontology of the district contains a brief description of the geology and advances evidence for the separation of the Jacalitos from the adjoining formations.

In a bulletin dealing with the geology and oil resources of the Coalinga district by Ralph Arnold and Robert Anderson⁴ the Jacalitos was described as being separable, at least faunally, from the Santa Margarita and Etchegoin formations. In this publication overlap was also used as evidence for the separation of the Jacalitos from the Etchegoin. The section on Jacalitos Creek was taken as the type section of the formation of that name, this being a part of the area covered by the present paper.

¹ Anderson, F. M., A Stratigraphic Study in the Mount Diablo Range of California, *Proc. Calif. Acad. Sci.*, 3d ser., vol. 2, no. 1, 1905.

² Anderson, F. M., A Further Study in the Mount Diablo Range of California, *Proc. Calif. Acad. Sci.*, 4th ser., vol. 3, 1908.

³ U. S. Geol. Surv., Bull. 396, 1909.

⁴ U. S. Geol. Surv., Bull. 398, 1910.

In a recent paper written essentially to show the economic possibilities of this region by R. W. Pack and W. English⁵ the Jacalitos and Etchegoin are grouped together as upper Miocene. In this paper, however, no faunal study is given of the relation of the Jacalitos to the other formations.

DESCRIPTION OF THE SECTION ON JACALITOS CREEK

The present paper is a study of the type section of Arnold and Anderson on Jacalitos Creek, and of the beds on Jasper Creek and Waltham Creek which are traceable directly into the type section. The description of the lithology and fauna may therefore be taken as representative of the Jacalitos at the type locality.

The area studied has in late geologic time been subjected to numerous structural disturbances. Tangential stresses have caused the beds to be folded into open anticlines and synclines. The axes of these folds are generally parallel to the major structural features of the district. A fault zone having a northwest-southeast trend cutting across the Diablo Range has greatly complicated the structure. This fault zone has the same general direction as the San Andreas fault a few miles to the west. Cross-faults are also numerous. These are, however, usually not of as great magnitude as those in a northwest-southeast direction. Due to faulting, some of the Tertiary formations are not exposed for considerable intervals. Both the determination of drainage lines and the elimination of formations by faulting are well shown along the upper part of Jacalitos Creek. For several miles this creek follows a fault of comparatively recent age, displacing the Santa Margarita(?) and the lowest portion of the Jacalitos beds. On following this in some places the lowest Jacalitos is found to be absent, while in others the Santa Margarita(?) shale has been entirely faulted out.

According to Arnold and Anderson, the thickness of the Jacalitos beds exposed at Jacalitos Creek is 3800 feet. The thickness of the section measured by them is probably too great, as beds apparently of Santa Margarita(?) age are included in it. The separation of these beds would, however, diminish the total thickness but slightly, the Santa Margarita(?) having an exposure of only a few hundred feet.

On Jacalitos Creek the Pliocene strata comprise essentially an alternation of soft coarse sandstone and conglomerate. In many of

⁵ U. S. Geol. Surv., Bull. 581-D, 1914.

the fossiliferous horizons the beds have been much indurated, causing these strata to outcrop prominently. Of minor importance are shale, rhyolitic tuff, and thin layers of coal. A bed of silicious limestone having a thickness of about ten feet was traced more than one-half mile until cut off by faulting. A short distance above and below the limestone marine fossils were found. The beds of coal, the coarseness of the sandstones and conglomerates, the variation of the lithology within short distances, and the character of the mulluscan fauna may be taken as indicative of deposition under shallow water conditions. The occurrence of quantities of gypsum at some localities, if it can be proved to be interstratified with the clastic rocks, may indicate that in part the beds are terrestrial or that the basin of deposition was nearly isolated from the sea.

FAUNA OF THE LOWER PLIOCENE ON JACALITOS CREEK AND WALTHAM CREEK

In the lower 800 to 1500 feet of the Jacalitos fossils are rare and where they appear the state of preservation is such that no diagnostic fauna has been obtained. In the upper horizons at some localities fossils occur in abundance. In most instances, however, the character of the material is not ideal for the preservation of the smaller forms, or the mulluscan shells have been crushed or leached out. In some parts of the area numerous faults limit the tracing of fossil horizons except for short distances. At a few localities the prominent indurated beds can be followed, otherwise the striking bands of white tuff, where present, are the best horizon markers.

The following list comprises the fauna obtained in the beds that have been mapped as Jacalitos at the type locality and the beds of corresponding age on Waltham Creek.

ECHINODERMATA

Astrodapsis jacalitosis Arnold
Astrodapsis peltoides Anderson and Martin
Echinarachnius gibbsii (Rémond)

PELECYPODA

<i>Arca trilineata</i> Conrad	<i>Cryptomya californica</i> (Conrad)
<i>Cardium quadrigenarium</i> Conrad	<i>Cryptomya quadrata</i> Arnold
<i>Chione elsmerensis</i> English	<i>Cumingia</i> , cf. <i>californica</i> Conrad
<i>Chione</i> , cf. <i>fernandoensis</i> English	<i>Cyrena californica</i> Gabb

Diplodonta parilis (Conrad)
Dosinia jacalitosana Arnold
Glycimeris coalingensis Arnold
Glycimeris septentrionalis (Middendorf)
Macoma baltica (Linne)
Macoma jacalitosana Arnold
Macoma nasuta (Conrad)
Macoma secta (Conrad)
Macoma vanvlecki Arnold
Metis alta (Conrad)
Modiolus rectus Conrad
Monia machroschisma (Deshayes)
Mulinia densata Conrad
Mytilus coalingensis Arnold
Mytilus kewi, n. sp.
Ostrea atwoodi Gabb
Pandora punctata Conrad
Panope generosa Gould
Paphia jacalitosensis Arnold
Paphia staminea (Conrad)
Paphia tenerrima (Carpenter)
Paphia, n. sp.?

Peecten estrellanus Conrad, var. *terminus* Arnold
Peecten (Hinnites) *giganteus* (Gray)
Peecten oweni Arnold
Peecten wattsi Arnold
Periploma, cf. *argentaria* Conrad
Phacoides annulatus (Reeve)
Phacoides richthofeni (Gabb)
Sanguinolaria nuttalli Conrad
Saxidomus nuttalli Conrad
Schizothaerus nuttalli (Conrad)
Siliqua lucida (Conrad)
Solen sicarius Gould
Spisula albaria (Conrad)
Spisula coalingensis (Arnold)
Spisula hemphilli (Dall)
Tellina aragonia Dall
Tivela trigonalis, n. sp.
Yoldia cooperi Gabb
Zirphaea, cf. *dentata* Gabb

GASTROPODA

Astrarium arnoldi, n. sp.
Calliostoma coalingensis Arnold
Calliostoma kerri Arnold
Calyptraea filosa (Gabb)
Cancellaria, cf. *tritonidea* Gabb
Chrysodomus coalingensis, n. sp.
Chrysodomus imperialis Dall
Chrysodomus portolaensis (Arnold)
Crepidula adunca Sowerby
Crepidula princeps Conrad
Ficus nodiferous Gabb
Fissuridea subelliptica, n. sp.
Margarita johnsoni Arnold
Murex perangulatus, n. sp.
Nassa californica (Conrad)
Natica (Neverita) *recluziana* Petit
Natica (Neverita) *orbicularis*, n. sp.

Olivella buplicata Sowerby
Purpura turris Nomland
Sinum scopulosum Conrad
Thais kettlemanensis Arnold
Thais lamellosa (Gmelin)
Trophon coalingense Arnold
Trophon magister, n. sp.
Trophon, cf. *carisaensis* F. M. Anderson
Turris (*Bathytoma*) *carpenteriana* (Gabb)
Turris (*Bathytoma*) *coalingensis* (Arnold)
Turris (*Bathytoma*) *tryoniana* (Gabb)
Turritella nova, n. sp.

CIRRIPEDIA

Balanus, cf. *conceavus* Bronn
Tamiosoma, cf. *gregaria* Conrad

Some of the forms in the Jacalitos fauna listed above warrant further discussion. *Astrodapsis jacalitosensis* Arnold, which has been thought characteristic of the middle Jacalitos, has been found within 200 feet of the top of the beds mapped by Arnold and Anderson. *Peecten oweni*

Arnold, *Pecten estrellanus* Conrad var. *terminus* Arnold, and *Echinarachnius gibbsii* Rémond have been found to have a range extending throughout the fossiliferous portion of the beds. A large number of species thought not to extend below the Etchegoin have been found to be of frequent occurrence in the Jacalitos. Among others may be mentioned *Turris* (*Bathytoma*) *coalingensis* (Arnold), *Trophon coalingensis* Arnold, *Calliostoma coalingensis* Arnold. *Pecten wattsi* Arnold, which has been considered characteristic of the beds of Etchegoin age, has been found at one locality well down in the Jacalitos.

PALAEONTOLOGIC DETERMINATION OF AGE OF THE JACALITOS BEDS

By increasing the Jacalitos fauna from 37 specifically determined forms to 82, the number listed in this paper, the close relationship of the Etchegoin and Jacalitos at once becomes apparent. Fifty-nine of the species listed in this paper are known to be present in the Etchegoin or younger formations. Twenty-six species are found also in the Santa Margarita-San Pablo and these are chiefly forms of long range.

The probable Pliocene age of the Jacalitos and Etchegoin has already been shown by the work of Professor J. C. Merriam⁶ and the writer⁷ for beds of corresponding age north of Coalinga.

DESCRIPTION OF SPECIES

ASTRALIUM ARNOLDI, n. sp.

Plate 10, figures 2a, 2b

Shell heavy, moderately elevated, five or more whorls, slightly convex at shoulder and periphery. Ornamented by about seven spiral cords, of which the anterior two are the heaviest. Incremental lines well defined, unequal; the crossing of these by spiral sculpture gives the shell a nodose appearance. A wide sulcus occurs between the lower of the heavy anterior cords and suture. Aperture oval, with thin outer lip. Base flattish, with about twelve nodose cords and wider interspaces. Umbilical region imperforate, concave, with peripheral and low median ridges. Dimensions of type: height, 48 mm.; maximum diameter, 48 mm.; minimum diameter, 38 mm.

⁶ Merriam, J. C., Tertiary Vertebrate Faunas of the North Coalinga Region, Trans. Am. Philos. Soc., vol. 22, part 3, Philadelphia, 1915.

⁷ Univ. Calif. Publ. Dept. Geol., vol. 9, no. 6, 1916.

Occurrence.—Type specimen from University of California locality 2523, on low hill immediately north of road from Alcalde to Robert's ranch, SE $\frac{1}{4}$, sec. 27, T. 21 S, R. 14 E, M. D. B. & M.

Associated with this form at the type locality are, among others, *Monia macroschisma* Deshayes, *Pecten estrellanus* Conrad var. *terminus* Arnold, *Pecten oweni* Arnold, *Phacoides annulatus* Reeve.

CHRYSODOMUS COALINGENSIS, n. sp.

Plate 10, figure 3

Shell fusiform, slender, seven or more whorls, spire high and acute. Axially sculptured with sharp longitudinal ribs extending from shoulder nearly to suture. Penultimate whorl with eleven ribs; on the body whorl axial ribs almost absent. Spiral sculpture on the upper whorls consisting of about seven prominent, nearly equal ribs with interspaces less than tops of ribs. Aperture narrow. Canal long, straight, thickened at base. Body whorl subangulate at shoulder, with side of whorl slightly convex, ornamented with about seventeen spiral ribs. Dimensions of type: height, 48 mm.; width, 17 mm.

This species may be easily distinguished from other members of the same genus by its slenderness, the high spire, and the long canal which widens near the base.

Occurrence.—University of California locality 2670, near top of 1600-foot hill, NW $\frac{1}{4}$ sec. 34, T. 21 S, R. 14 E, M. D. B. & M.

FISSURIDEA SUBELLIPTICA, n. sp.

Plate 10, figures 5a, 5b

Shell subelliptical, moderately elevated, gently convex, apex slightly anterior. Radially sculptured by numerous equal ribs. On type specimen concentric growth lines prominent, some more developed than others. Apical orifice large, elliptical, anterior to apex. Dimensions of type: height, 24 mm.; maximum diameter, 56 mm.; minimum diameter, 46 mm.

Occurrence.—University of California locality 2664, NE corner of NW $\frac{1}{4}$ sec. 34, T. 21 S, R. 14 E, M. D. B. & M.

At the type locality this species occurs with the following characteristic lower Pliocene species: *Phacoides annulatus* (Reeve), *Pecten oweni* Arnold, *Cancellaria*, cf. *tritonidea* Gabb, *Chrysodomus portolaensis* Arnold, *Turris* (*Bathytoma*) *coalingensis* (Arnold), *Turritella nova*, n. sp.

MUREX PERANGULATUS, n. sp.

Plate 11, figures 1a, 1b

Shell heavy, six or seven whorls, with three prominent thick varices which are continuous from body whorl up the spire. Spire low with indistinct slightly appressed suture. Spiral sculpture consisting of (on the body whorl seven and on the others two) prominent somewhat nodose ribs, on last whorl an intercalary occurs between each pair. Canal open, straight. Outer lip slightly thickened, margin sharp, internal spiral lines continue to edge, anterior part projects about 5 mm. in front of columella. Inner lip smooth, columella imperforate. Dimensions of type: height, 45 mm.; width, 27 mm.

This species resembles somewhat *Purpura foliata* Martyn, but differs in having apparently no anterior tooth or spine characteristic of that genus, open canal, a low spire, and a projecting and not as much thickened outer lip.

Occurrence.—University of California locality 2649, on ridge above Coalinga-Priest Valley road, SE $\frac{1}{4}$ sec. 19, T. 21 S, R. 14 E, M. D. B. & M.

MYTILUS KEWI, n. sp.

Plate 9, figure 1

Shell elongate ovate, of moderate thickness. Surface sculptured by numerous unequal incremental lines and minute radiating striae. A wide depressed area passes from slightly above the beak to about middle of base. Beak terminal, somewhat curved. Posterior end regularly rounded. Posterior dorsal margin slightly arcuate, with small angulation a little more than one-half of the distance from the beaks to the anterior end. Base straight except slight arch where it meets the depressed area. Dimensions of type, which is a small specimen: length, 86 mm.; height, 45 mm.; maximum diameter, 34 mm.

This species seems to be rather closely allied to *Mytilus expansus* Arnold, which occurs in the lower Miocene. *M. expansus* Arnold has, however, a broader posterior outline and the depressed area is not as well marked. *M. kewi*, n. sp., differs from *M. coalingensis* Arnold, which also occurs in the Jacalitos beds, by being smaller, having less acute and not as much thickened beak, and in the depression extending from beak to basal margin.

Occurrence.—University of California locality 2680, near top of ridge at center of NW $\frac{1}{4}$ sec. 8, T. 22 S, R. 15 E, M. D. B. & M.

NATICA (NEVERITA) ORBICULARIS, n. sp.

Plate 10, figures 4a, 4b

Shell globular, heavy, about five or six whorls, spire slightly elevated. Sculptured by unequal oblique incremental lines. Body whorls large, with marked convexity at shoulder, giving sides and top a flattened appearance. Aperture ovate, with slightly thickened outer lip. Umbilicus partly covered by callus extending from lower portion of inner lip to upper portion of outer lip, with a sharp angle near the middle, and is marked by a deep groove about one-third of distance from posterior end. Height, 38 mm.; maximum diameter, 44 mm.

This species differs from *Neverita recluziana* Petit by its more flattened sides, dome-shaped spire, less callused umbilical area, and greater convexity at shoulder of whorls.

Occurrence.—Found at numerous localities in the Jacalitos and Etchegoin. Type from University of California locality 2679.

TIVELA TRIGONALIS, n. sp.

Plate 9, figures 2a, 2b, 2c

Shell thick, trigonal, inequilateral, equivalve. Umbones small, about two-thirds of distance from anterior end. Base gently arcuate. Anterior dorsal edge nearly straight, depressed. Anterior extremity evenly rounded. Posterior dorsal margin straight, much thickened. Posterior end bluntly rounded to subangulate. Three thick cardinal teeth in each valve, the middle left bifid, anterior lateral of left valve heavy. Nymph plates very prominent grooved. Height, 41 mm.; width, 55 mm.

Although somewhat similar to the Recent *Tivela stultorum* Mawe, *T. trigonalis*, n. sp., may easily be distinguished from that form by being more inequilateral, thick, depressed posterior dorsal margin, and greater prominence of nymph plates.

Occurrence.—Middle Jacalitos to lower Etchegoin, University of California localities 2684, 2104.

TROPHEON MAGISTER, n. sp.

Plate 11, figures 4a, 4b, 4c

Shell very large, robust, thick, height of spire variable. Whorls five or more, slightly convex, with appressed suture. Body whorl sharply angulated at base and shoulder, giving the top a tabulate

appearance. Each whorl ornamented by nine or ten prominent varices, which at angles of whorl produce nodes or short spines which become stronger with age. Immediately under body whorl is a deep groove or canal, in front of which the anterior portion of whorl protrudes. Aperture large, angular, with simple outer lip. Canal long, recurved. Height of imperfect type, 92 mm.; diameter, 70 mm.

This species has heretofore been identified as *Trophon ponderosum* Gabb. From this it differs by much larger size, stronger angulation at base of body whorl, longer canal, and in having the deep groove at base of last whorl. *Trophon carisaensis* F. M. Anderson is apparently a close relative of this form, but differs from *Trophon magister*, n. sp., in smaller size, more prominent upper and less prominent lower nodes on body whorl, suture being higher up on posterior whorls, and the smaller angle which the upper surface makes with the axis of shell.

Occurrence.—Type from University of California locality 2098, NW $\frac{1}{4}$ sec. 24, T. 21 S, R. 14 E, M. D. B. & M. This species occurs commonly in the upper portion of the Jacalitos beds.

TURRITELLA NOVA, n. sp.

Plate 11, figure 3

Shell turreted, whorls flat, with well-defined depressed suture. Between the two more prominent spiral ridges, but somewhat nearer the upper is a narrow groove. Immediately above and also immediately below the suture is a low ridge. Between the low ridge above the suture and the heavier of the two ridges near the middle of the whorl is a wide groove, giving a distinctly excavated appearance to this portion of the whorl. Diameter, 11 mm.; height unknown.

This form is decidedly similar to *Turritella cooperi* Carpenter, of which it is probably the precursor. It differs, however, in having the narrow middle groove, the minor ridges near the suture, and the excavated area at the lower part of the whorls.

Occurrence.—Type from University of California locality 2533, NE $\frac{1}{4}$ sec. 29, T. 21 S, R. 14 E, M. D. B. & M., on west bank of Waltham Canyon.

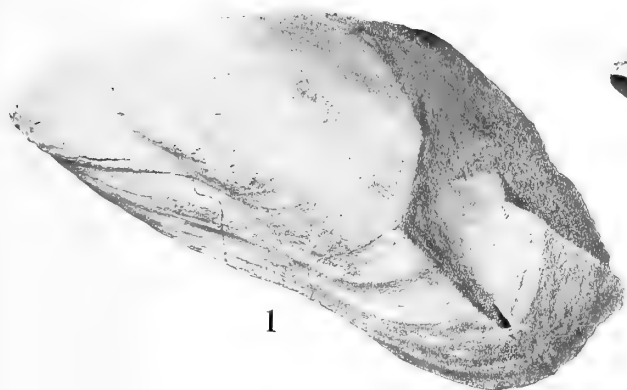
Associated with this species are found in the type locality *Macoma vanvlecki* Arnold, *Pecten estrellanus* Conrad var. *terminus* Arnold, *Pecten oweni* Arnold, *Cancellaria tritonidea* Gabb, *Ficus nodiferous* Gabb, *Turris* (*Bathytoma*) *coalingensis* Arnold, *Thais kettlemanensis* Arnold, *Turris* (*Bathytoma*) *tryoniana* (Gabb).

Transmitted October 1, 1915.

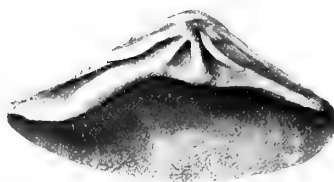
EXPLANATION OF PLATE 9

All figures natural size

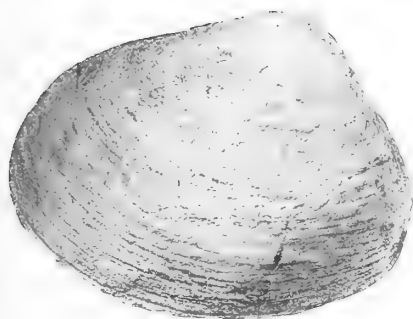
- Fig. 1. *Mytilus kawi*, n. sp. Exterior of imperfect left valve.
Fig. 2a. *Tivela trigonalis*, n. sp. Exterior of left valve.
Fig. 2b. *Tivela trigonalis*, n. sp. Interior view of right valve.
Fig. 2c. *Tivela trigonalis*, n. sp. Interior view of left valve.
Fig. 3a. *Chione elsmerensis* English. Exterior view.
Fig. 3b. *Chione elsmerensis* English. Interior view of left valve.



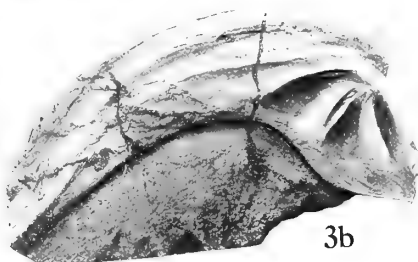
1



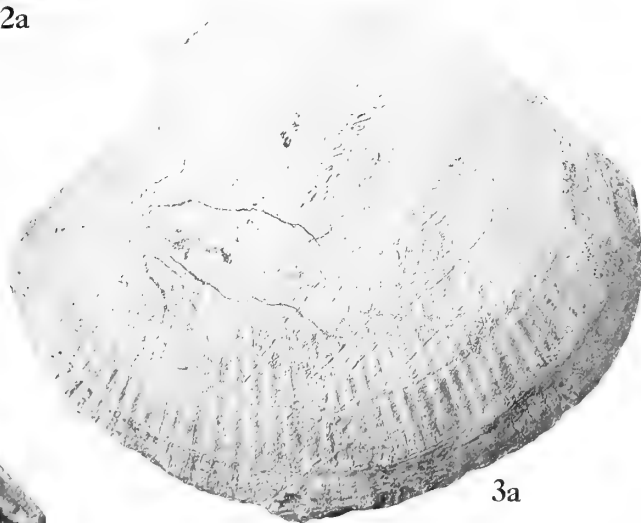
2b



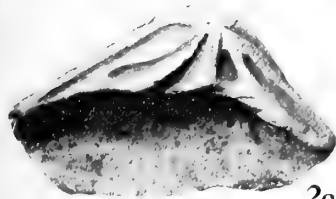
2a



3b



3a



2c

EXPLANATION OF PLATE 10

All figures natural size

- Fig. 1. *Chione elsmerensis* English. Interior view of right valve.
- Fig. 2a. *Astralium arnoldi*, n. sp. Upright view of imperfect specimen.
- Fig. 2b. *Astralium arnoldi*, n. sp. Basal view.
- Fig. 3. *Chrysodomus coalingensis*, n. sp. Back view.
- Fig. 4a. *Natica (Neverita) orbicularis*, n. sp. Back view.
- Fig. 4b. *Natica (Neverita) orbicularis*, n. sp. Basal view.
- Fig. 5a. *Fissuridea subelliptica*, n. sp. View from above.
- Fig. 5b. *Fissuridea subelliptica*, n. sp. View in profile.



1



2b



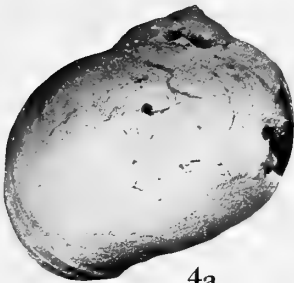
4b



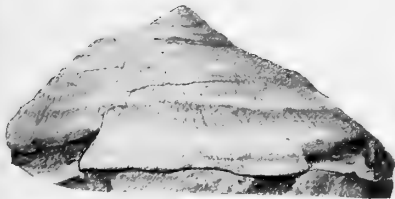
3



2a



4a



5b



5a

EXPLANATION OF PLATE 11

All figures natural size

- Fig. 1a. *Murex perangulatus*, n. sp. Mouth view of type.
Fig. 1b. *Murex perangulatus*, n. sp. Back view of same specimen.
Fig. 2a. *Trophon coalingense* Arnold. A small specimen.
Fig. 2b. *Trophon coalingense* Arnold. Mouth view of a young specimen.
Fig. 3. *Turritella nova*, n. sp. Type specimen.
Fig. 4a. *Trophon magister*, n. sp. Back view of type specimen.
Fig. 4b. *Trophon magister*, n. sp. Back view of a small specimen.
Fig. 4c. *Trophon magister*, n. sp. An extreme variation of this species.



1a



1b



2a



2b



3



4b



4c



4a



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BULLETIN OF THE DEPARTMENT OF

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Issued February 29, 1916

THE PLIOCENE OF MIDDLE AND NORTHERN CALIFORNIA

BY

BRUCE MARTIN

UNIVERSITY OF CALIFORNIA PRESS

BERKELEY

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INTRODUCTION

Within the past two years the writer has examined a number of the Pliocene formations of California for the purpose of bringing together a more complete fauna than had heretofore been obtained, hoping also to throw some light on the faunal relations of the formations, and to make possible a more exact correlation of the beds concerned. It is the purpose of this paper to give the results obtained in this investigation. The formations included in the examination are: the Merced Series at Seven Mile Beach, San Mateo County, and at several other localities to the north and to

to the south; the Purisima Formation south of Halfmoon Bay, San Mateo County; the later Neocene formations of the Sargent Oil Field; and the Wildcat Series in Humboldt County, California.

REVIEW OF THE LITERATURE

Aside from the incidental references to the geology of the Pacific Coast made by the early scientists and explorers, such as Captain Beechey and others, there are numerous publications which have contributed much to our knowledge of the later Tertiary and Quaternary formations of this region. The more important of these papers will be briefly reviewed in their chronological order.

Among the earliest publications is one by Dr. John B. Trask, in which he discusses the geology of the Coast Range Mountains. In this paper he defined the Santa Cruz Mountains and described the geology of that region.¹ He applied the name "infusorial group" to the shales now known as the Monterey shales. He described slates and sandstones overlying the Monterey and found them fossiliferous. The latter are probably the beds that are now known as the Purisima Formation.

In 1856 Dr. W. P. Blake published an account of the geology of the San Francisco Bay region.² The stratigraphy and lithology of the beds exposed along the shores adjacent to the Golden Gate and of the islands in the bay were fully discussed. The series of sediments were considered to be of Tertiary age from fragments of rocks washed upon the beach, near Point Lobos, containing fossil echinoderms (*Scutella interlineata*), which he supposed to be the same rocks as those exposed at Point Lobos in place. The fragments containing *Scutella interlineata* probably came from the Merced Series several miles farther south, which he apparently omitted from the discussion.

In 1865-66 the Geological Survey of California made a survey of the coast region from San Francisco Bay south to San Diego.³ The beds at Seven Mile Beach were called Pliocene, on the authority of Gabb and Rémond, and were said to be overlain by Post-Pliocene sediments. The formations exposed along the coast south of Half-

¹ Senate Doc. no. 14, State of California, Session 1855.

² Pacific Railroad Reports, vol. 5, pp. 145, 1856.

³ Geol. Survey of Calif., J. D. Whitney, State Geologist, Geol. vol. 1, p. 61.

moon Bay were classed as Miocene Tertiary, and those at Año Nuevo Bay as Pliocene.

A list of California fossils, together with their geological and geographical range, was compiled and published in 1888 by Dr. J. G. Cooper in the Seventh Annual Report of the State Mineralogist.⁴ In general the formations at Halfmoon Bay and Seven Mile Beach were considered to be Pliocene. Some of the beds between Halfmoon Bay and Santa Cruz were classed as Miocene.

In 1893 Professor A. C. Lawson published the first complete description of the marine sediments at Seven Mile Beach and applied the name "Merced Series."⁵ In discussing this series Professor Lawson described the structural and stratigraphic features and the various lithological types. He also gave a faunal list which, according to Dall and Cooper, was indicative of the Pliocene. The unconformable relations between the Merced Series and the overlying brown and tawny sands designated the "Terrace Formations," was briefly discussed. The beds at Pillar Point were included in this discussion, and those south of Halfmoon Bay were referred to.

During the same year Professor Lawson published his "Sketch of the Geology of the San Francisco Peninsula,"⁶ in which he reviewed the previous work on the Merced Series and brought out more strongly the proof of the fault along the south side of San Bruno Mountain along which movement took place, letting the strata of the Merced Series down against the rocks of the Franciscan Series of which San Bruno Mountain is composed. This brought out more clearly the stratigraphic relations of the whole series and the structural origin of Merced Valley. A small addition was also made to the faunal list which indicated the Pliocene age of this series.

During the summer of 1894 Professor Lawson made a reconnaissance trip north along the coast from San Francisco to Eureka.⁷ The account of this trip contains a description of the Neocene sediments which occur in the Eel River Valley. The limits of the area over which these beds occur was not defined, but two cross-sections were made, one at Ferndale and the other at Scotia, giving the

⁴ Calif. State Mining Bureau, Seventh Annual Report of the State Mineralogist, 1888.

⁵ Univ. Calif. Publ. Bull. Dept. Geol., vol. 1, pp. 115-160, 1893.

⁶ U. S. Geol. Survey, Fifteenth Annual Report, p. 459, 1893.

⁷ Univ. Calif. Publ. Bull. Dept. Geol., vol. 1, p. 255, 1894.

structure and the lithology of the formation. The name "Wildcat Series" was applied to the beds, from their typical development in the Wildcat country south of Ferndale. A collection of fossils made by Professor Lawson, principally from the middle and upper portions, and identified by Dr. J. C. Merriam, warranted the determination of these beds as Pliocene.

In 1895 George H. Ashley published an account of the Neocene stratigraphy of the Santa Cruz Mountains.⁸ In this paper he reviewed the work of previous writers and gave the results of his own investigations, which appeared to show that the beds, now known as the Purisima Formation, were very closely related to the Merced Series at Seven Mile Beach, but contained more of the Miocene forms and were therefore placed between the Miocene and the Pliocene and were called the "Transition Beds." Ashley also suggested the possibility that the lower portion of the Merced Series at Seven Mile Beach might have been faulted down, and that this faulted portion was the equivalent of his "Transition Beds" south of Halfmoon Bay. He did not discover any widespread unconformity between the Monterey and the Merced Series, and was of the opinion that sedimentation was continuous from the beginning of Monterey time to the end of the Merced, the disturbances which had effected this region taking place at the close of Merced time. The uppermost Merced was placed in the Pliocene because of the degree of folding to which it had been subjected and because it was covered by later sediments, the terrace formations. He considered that the evidence was insufficient to establish an unconformity between the upper and the lower portions of the Merced, although it was apparent that either faulting had taken place or an unconformity existed in the neighborhood of Thornton Station.

The "Topographic Development of the Klamath Mountains"¹⁰ published by J. S. Diller in 1892 contains a condensed description of the Tertiary and Quarternary formations occurring along the coast of Oregon and California from the mouth of the Coquille River to Cape Mendocino. The stratigraphy and the lithology of the Wildcat Series was amply described. Inserted with Diller's description are notes by Dr. W. H. Dall concerning the age of the beds. The Wild Cat was doubtfully considered upper Miocene, being

⁸ Proc. Calif. Acad. Sci., 2nd series, vol. 5, 1895.

¹⁰ U. S. Geol. Surv. Bulletin, 196, p. 30, 1902.

certainly younger than the Empire Beds of Coos Bay and older than the Merced south of San Francisco. In a later note, inserted in the same publication (page 39), Dr. Dall reported, after having visited the region himself, "that the characteristics of the fauna point to an upper Miocene age and no distinctly Pliocene species of mollusks appear in it anywhere." Some of the sands and gravels toward the ocean appeared to be quite recent and it was considered by Dall that these might even be Pleistocene. The deposition of this series was considered continuous from the upper Miocene to some time in the Pliocene without a marked unconformity, "and with a continuous fauna which changed, if at all, chiefly by some species becoming more rare or disappearing entirely."

Along Mad River, between North Fork and the mouth of Cañon Creek, a formation of soft sandstone was exposed which formed the low hills along the east side of the coastal plain. A small number of fossil marine mollusks obtained from these beds were identified by Dr. Dall, who questionably placed the beds in the Pliocene.

At Battery Point, near Crescent City, California, a section is described at the base of which is a formation of soft bluish sandstone containing pebbles and a few fossil invertebrates, among them *Terebratalia hemphilli* Dall, which points toward a Pliocene age. Above this member there are non-fossiliferous yellowish sands and clays with some pebbles at the base. The whole series is unconformable above a much altered sandstone of Pre-Tertiary age.

A similar section is exposed at Pebble Beach, two miles north of Crescent City. Here the bluish sandstone containing *Terebratalia hemphilli* is apparently lacking, and the soft non-fossiliferous yellowish sand is lying horizontally upon Miocene strata which were tilted slightly to the northwest. The Miocene beds were unconformable upon the much altered Pre-Tertiary sandstone.

At Point St. George, a few miles north of Crescent City, Diller described a formation of soft yellowish and gray shaly sandstone and whitish shale, less than one hundred feet in thickness, which contained a fauna that warranted its determination as Miocene of the Empire horizon.

At Cape Blanco, Oregon, about forty miles north of the California boundary, Diller described Neocene and Quarternary sediments which are more or less closely related to the later Tertiary formations of California. The Neocene is represented by a series of yellow sandstones, tuff, light-gray sand beds, conglomerate, and

argillaceous sand with calcareous nodules. This series was named the Cape Blanco Beds and correlated with the Empire of Coos Bay on palaeontological evidence. This formation was reported to extend from Cape Blanco to the mouth of Elk River, where it was seen to dip beneath the beach sand. The sediments also occur along the cliffs north of Black Lock Point. Overlying unconformably the Cape Blanco Beds were a series of sands and gravels, the lower portion of which was very fossiliferous. This series was named the Elk River Beds. A collection of fossils made by Diller was submitted to Dr. Dall who made the following report: "They are probably Pleistocene, all of the species seeming recent, but they may be of the Merced horizon; they are not older than the newer Pliocene." Diller thought that the interval between the Cape Blanco Beds and the overlying Elk River Beds might represent a long period and that the Merced and the Wilcat formations were deposited during that time.

In 1903 Ralph Arnold published a memoir on the "Palaeontology and Stratigraphy of the Marine Pliocene and Pleistocene of San Pedro, California."¹¹ In this publication the author correlates a number of the Pliocene and Quarternary formations along the coast with those at San Pedro. The greater part of the Merced Series is considered to be above the San Pedro and the San Diego Pliocene.

The Proceedings of the American Philosophical Society contains an article by Haehl and Arnold which deals with the diabases of the Santa Cruz Mountains.¹² In this paper a new formation is described to which the name Purisima is given. This formation consists of conglomerates, fine-grained sandstones, and shales which were typically developed in the vicinity of Purisima Creek, San Mateo County, California. The beds were found to be unconformable upon the Vaqueros sandstone and the Monterey shale, and at the top graded into beds having a fauna somewhat similar to that of the Merced Formation. The individuality of the fauna, stratigraphy, and the lithology of this formation appeared to warrant the application of a new and distinct name. The formation was thought to represent the middle and the lower portion of the Pliocene.

In 1905 Vance Osmont described a geological section across the coast ranges north of San Francisco Bay.¹³ In this section he re-

¹¹ Calif. Acad. Sci., Memoirs, vol. 3, 1903.

¹² Proc. Amer. Phil. Soc., vol. 43, pp. 22-24, 1904.

¹³ Univ. Calif. Publ. Bull. Dept. Geol., vol. 4, pp. 39-87, 1905.

ports the occurrence of marine Pliocene which he correlated with the Merced Series at Seven Mile Beach, but thought that they might represent the lower portion, such as the beds at Capitola, there being an abundance of *Arca trilineata* Conrad. These beds were resting upon a formation of volcanic ash, called by Osmont the Sonoma Tuff. In some localities the tuff was associated with sandstones and conglomerates, and in other localities with lava flows. Conformably beneath the Sonoma tuff occurred the Mark West andesite. This series of formations, including the St. Helena rhyolite which conformably overlies the Merced, rests unconformably upon the Orindan Formation. The fauna obtained from the marine sediments, in the neighborhood of Wilson's Ranch, seemed to warrant the correlation with the beds at Seven Mile Beach. The thickness of the formation was in the neighborhood of two thousand feet.

In 1906 Ralph Arnold published a monograph on the Tertiary and Quaternary Pectens of California.¹⁴ In this publication the author gives a short review of each of the typical formations of the Tertiary and Quaternary of California. He included a faunal list for each formation and correlated them on that basis. The greater portion of the Purisima Formation was placed unquestionably in the Pliocene, although the lower portion was closely related to the Miocene. The Merced Series was both Pliocene and Pleistocene, the greater portion being placed in the upper Pliocene. Both the Purisima and the Merced horizons were recognized in the Wildeat Series in Humboldt County.

The "Geologic Record of California," a paper published in 1910 by Dr. J. P. Smith,¹⁵ contains a correlation table which includes formations from the Archaean to the present. The Merced Series is placed in the upper Pliocene and the Purisima Formation in the lower Pliocene and uppermost Miocene.

The geology of the Sargent Oil Field, Santa Clara County, California, was worked out and published in 1911 by William F. Jones.¹⁶ The formations concerned in the geology of this area include both igneous and sedimentary from the Franciscan to the present. Only the upper Miocene and the Pliocene are to be considered in this paper. The Monterey shale is the most extensive and well developed of the formations represented. Unconformably overlying the Mon-

¹⁴ U. S. Geol. Surv. Professional Paper no. 47, 1906.

¹⁵ Journal of Geology, vol. 18, pp. 216-226, 1910.

¹⁶ Univ. Calif. Publ. Bull. Dept. Geol., vol. 6, pp. 55-78, 1911.

terey there is a formation composed principally of coarse-grained to conglomeratic sandstone, portions of which are azure blue in color and somewhat resemble part of the San Pablo. On this character Jones has depended for its correlation with the San Pablo, which name he has applied to the formation. Overlying his San Pablo unconformably is his Merced and Purisima. This formation is about fifteen hundred feet in thickness. It is composed principally of medium and coarse-grained gray sandstone. The correlation of this formation with the Merced and the Purisima was made upon palaeontological evidence.

Dr. J. P. Smith has recently published a paper on the Miocene invertebrate faunas of California.¹⁷ In this paper the author gives a faunal list which include all of the species so far known from these formations, together with the life range of each species. The division between the Miocene and the Pliocene was drawn between the Etchegoin and the Purisima as a matter of convenience, "there being no natural boundary between the two periods." The Purisima was placed with the San Diego Formation and classed as lower Pliocene. The Merced Series, together with the Santa Barbara, was considered to be upper Pliocene. The name Merced was not used in connection with any of the formations in the south because it was not certain that the term Merced Series was applicable to such formations.

MERCED SERIES

Aside from the Merced Series at Seven Mile Beach, there are, in the vicinity of San Francisco Bay, numerous other occurrences of marine sediments which have been recognized as being contemporaneous in deposition with those at the type locality, and to which the name Merced has been applied. One of the largest of these occurrences is to be found in the Santa Rosa Valley a few miles north of the city of Santa Rosa. Another rather large area occurs in the Pajaro River Valley near Sargent Station, Santa Clara County, California. Three smaller areas are situated along the coast, one at Año Nuevo Bay, another at Pillar Point, and the third at the entrance to Bolinas Bay. There are other marine sediments in this general region, portions of which are the equivalent of the Merced Series at Seven Mile Beach, but these formations have been

¹⁷ Proc. Calif. Acad. Sci., 4th series, vol. 3, pp. 161-182, 1912.

described under another formation name. The general stratigraphic and lithologic features of each formation will be briefly outlined before the faunal correlation is attempted.

MERCED OF THE TYPE LOCALITY

Physical Features.—The type section of the Merced Series occurs on the San Francisco Peninsula about eight miles south of the Golden Gate. The area covered by these beds lies in the form of an elongate trapezoid extending diagonally across the peninsula from Seven Mile Beach southeast to San Francisco Bay. The southwestern boundary is a nearly straight line. From Mussel Rock it follows a course southeast to Lake San Andreas and thence eastward toward San Mateo. The northeastern limits of this area are marked by a fault scarp along the south flanks of San Bruno Ridge. Professor Lawson has shown that this fault scarp, which is somewhat obscured by the valley alluvium, is the line along which movement took place, letting the Merced Series down against the Franciscan of San Bruno Mountain, and that this downthrow, along the northeastern border, gave the latter its monoclinical structure.

The general stratigraphic characters of these sediments were described by Professor Lawson as follows:

From the basement at Mussel Rock the strata of the Merced Series are well exposed in ascending sequence to Lake Merced. The edges of the strata form the sea-cliff for the entire distance. The sea-cliff is in active recession, so that fresh exposures of the rocks are afforded throughout the section. The strike is for the most part more or less transverse to the shore, and the latter is a simple, nearly straight line. The rocks are tilted, generally at high angles, and have a monoclinical structure for the entire length of the section. . . . There is no repetition of strata, and fault structure is represented only by very minor dislocations. In a word, the section is ideally simple, and is eminently susceptible of approximately accurate measurement for the thickness of the series. There is but one drawback, and that consists of two landslides which scar the face of the cliff. . . . The cliff at its highest is about 720 feet above the shore, and at several places the strata may be seen extending from the shore to the top of the cliff with uniform dip.¹⁸

These beds are resting upon the eroded surface of the Franciscan Series, which is a prominent formation in the Coast Range Mountains. The contact between these two formations is marked by a very distinct change in lithology and a very pronounced dif-

¹⁸ Lawson, A. C., Post-Pliocene Diastrophism of the Coast of California, Univ. Calif. Publ. Bull. Dept. Geol., vol. 1, p. 143, 1893.

ference in attitude of the strata. From Mussel Rock north to the landslide at Thornton Station the beds have an average dip to the northeast of fifty or sixty degrees. The strike for this section varies between north forty and north sixty degrees west. Beyond Thornton Station the strike is nearly parallel to the cliff with a small east dip. The sudden and marked change in the attitude of the strata at this point commands more than the usual interest. The lithological character of the rocks appears not to be greatly different in the two sections, but the suggested stratigraphic discordance, together with the faunal break, which will be discussed on a following page, suggests the possibility of an unconformity, and warrant separation of the series into an upper and a lower horizon.

The rocks of the Merced Series consist of fine-grained gray sandstones and sandy shales, usually soft and friable, being little more than compact sand. Occasionally thin, hard calcareous layers and thin lignitic layers are interstratified with the softer material. In a few localities, near the base of the series, a small amount of conglomerate was observed. With this exception the sediments are principally fine-grained soft sandstone and clays.

One of the most remarkable lithological features of the whole series is the occurrence of a large area of shell agglomerate in the higher portions of the hills one and one-quarter miles south and a little west of Baden Station. The strata are composed almost entirely of fragments of marine shells. Fine sand and gravel compose the ground-mass in which the shell fragments are embedded. This deposit marks an old beach line or littoral zone and is important in showing the shallow-water conditions which existed during a part of Merced time. The total thickness of the Merced Series, as measured by Professor Lawson, amounts to a little more than one mile.

The Merced Series is overlain, unconformably, by a belt of nearly horizontal deposits which stretch entirely across the peninsula from the ocean beach to San Francisco Bay. These deposits are composed principally of light-yellow and brown sands and clays, with occasional seams of gravel and lignitic material near the base. At least a part of these sediments were designated the Terrace Formations by Professor Lawson in a publication to which reference has previously been made. The term "Terrace Formations" as used in this publication may include more than was originally included by Professor Lawson. Together with the allu-

vium and surface soils they entirely cover the floor of the Merced Valley and extend far back on the hills to considerable elevations, manteling a large portion of the Merced Series.

In general, the relations of the Terrace Formations to the underlying series are obscure. Between the ocean beach and Lake Merced, north of Thornton Station, the strata of the upper horizon of the Merced Series, the Gasteropod Zone, are only very gently inclined toward the north and east. The overlying Terrace Formations are poorly stratified and it is a difficult matter to locate a difference in attitude of the two formations. In the sea-cliff about one mile south of the outlet to Lake Merced Professor Lawson recognized an erosion surface. The occurrence of dark brown, somewhat peaty, beds immediately above the erosion surface suggested to Professor Lawson the possibility that this might mark the base of the Terrace Formations.

In laying its track from San Francisco to Halfmoon Bay the Ocean Shore Railroad Company has cut a bench in the sea-cliffs from Thornton Station to Mussel Rock. A few hundred yards south of Thornton Station the railroad cuts have exposed a good section in which a distinct unconformity may be observed. This unconformity is marked by an erosion surface and a difference in attitude of the strata. The beds above the erosion surface consist of rather coarse sands, gravels, and clays. The underlying strata are a part of the Merced Series and are probably the upper part of the lower horizon instead of the upper horizon found north of Thornton Station. This unconformity is considered to mark the base of the Terrace Formations.

In following up any of the larger creeks which cut across the strike of the strata of the Merced Series, south and southeast of Colma, one usually finds the soft, unconsolidated, light-yellowish sands and clays in the lower portions of the streams. The erosion of these sediments is quite characteristic and resembles the Bad Lands topography. The stratification is not well marked, but occasionally bedding planes can be observed and they are usually horizontal. In continuing up stream the gray sandy shales of the Merced Series are encountered. The stratification of the latter is inclined northward at considerable angles. At no place in these sections is it possible to find the exact contact between the two formations, but the zone of separation can be quite easily located. It crosses the larger creeks at about the two hundred or two hun-

dred and fifty-foot contour line, or where the topography changes abruptly from the gentle slopes of the Merced Valley to the steeper slopes of the adjoining hills. The difference in the character of the sediments, the difference in attitude of the strata, together with the fact that they are in places separated by an erosion surface, makes it clear that the Terrace Formations and the later Quarternary deposits are lying unconformably upon the Merced Series.

The upper horizon of the Merced Series has not been recognized in the sections south and southeast of Colma. Its absence from these sections may be explained by considering that a portion of the Merced Series (that portion south and southeast of Colma) was being subjected to erosion while the upper horizon, north of Thornton Station, was being deposited.

The Terrace Formations consist principally of light-yellowish sands and clays. There are numerous seams of gravel and coarse sand interstratified with the finer sediments. Lignitic material and well-preserved pieces of wood are not uncommon in the basal portion of the series. One of the most noteworthy occurrences of wood may be observed in the banks of one of the larger creeks one mile nearly due south of Colma. Here the trunks of large trees project out of the creek banks, in some cases extending across the creek into the opposite bank. These trees are buried beneath several hundred feet of sediments. In nearby streams the strata of the Merced Series outcrops in the creek bottom, indicating that the trees occur near the base of the Terrace Formations or later Quaternary deposits. It seems probable that they existed on the land surface of the Merced Series prior to the deposition of the later sediments. The origin of these formations is to be accounted for in a number of ways. It is the opinion of the writer that they are not to any extent marine deposits, but that they are mainly sediments that have been deposited in swamps, lagoons, and in fresh-water lakes; and to a less extent, are alluvial wash and sand-dune accumulation. They are the equivalent of at least a portion of the Santa Clara Formation and the Quaternary gravels overlying the Santa Clara Formation.

Fauna.—The fauna of the Merced Series, of the type section, has not generally been considered to be distinctly determinative. This has been due to the absence of certain characteristic forms, such as the pectens, which are frequently relied upon to a great extent as horizon determiners. The collections of Cooper, Lawson,

Ashley and others have usually been characteristic enough to justify the determination as Pliocene, but they have not been sufficient to assign any particular part of the Merced to a certain division of the Pliocene. Some palaeontologists who are familiar with California geology have considered the series to be upper Pliocene. The reasons for such a determination are to be found in the relation which the Merced bears to formations outside of the area rather than the fauna found within the Merced itself. At Año Nuevo Bay, a short distance to the south, a small area of Merced is reported to occur conformably above the Purisima Formation. The faunal and stratigraphic relations of the Purisima appear to indicate that it is lower Pliocene in age. From the superposition of the Merced upon the Purisima it is evident that the Merced is at least later than lower Pliocene.

Recent collecting over the whole area covered by the Merced has revealed fossil invertebrates from the entire vertical range and also from the greater portion of its lateral extent. Numerous creeks and small streams cut transversely across the section from its southwestern boundary to the Merced Valley. In nearly every one of these streams good exposures are to be found, and fossil localities, while not numerous, are usually found in all of these sections. The hills immediately to the southwest of Millbrae have afforded several localities from which a large number of fossil leaves were obtained, as well as fossil invertebrates. Unfortunately the generic and specific character of the leaves could not be determined, consequently they give no evidence as to the age of the beds in which they were found. They are of value, however, in showing the character of the deposit, clearly defining it as an estuarine or littoral zone. To the southeast of Millbrae good exposures rarely occur on account of the alluvium and sand-dune deposits which conceal the underlying beds. To the northwest the outcrops become much more numerous and accessible, and the state of preservation of the fossils much better as the ocean beach is approached.

The most satisfactory and accessible section for a faunal study is the one exposed along the sea-cliff from Mussel Rock to the outlet of Lake Merced. In general, fossil localities are not as numerous as those found in other sections, but the excellent exposures of the strata afford good opportunities for investigation. Near the base, just above the contact at Mussel Rock, several localities

have yielded as high as fifteen or twenty species. Occurring as they do at this locality they are of more than usual value. A short distance south of Thornton Station, on the Ocean Shore Railroad, a number of hard concretionary strata occur interstratified with softer material. In these strata numerous well-preserved echinoderms, *Scutella interlineata* Stimpson, occur. They are also numerous in the localities a short distance above the base of the section, but so far as the writer's experience goes they have not been found above the locality a few hundred yards south of Thornton Station. Along the sea-cliffs north of Thornton Station fossils are fairly abundant. Some of the strata exposed, just above the base of the cliffs, are almost entirely composed of small gasteropods and pelecypods. These localities have previously been referred to as the "upper gasteropod zone". The most peculiar feature of this faunal horizon is that ninety per cent or more of the species found here are also found living. All of the twenty species collected from this horizon by the writer were recognized as belonging to the Recent fauna. On the evidence obtained from the percentage of living species Ralph Arnold has referred this upper Merced to the Pleistocene age, while the greater portion of the Merced, stratigraphically underlying it, has been placed in the preceding period. From the faunal relations there seems to be little doubt that Arnold's determination is approximately correct. The close resemblance between the Recent fauna and that of the upper Merced seems to suggest the possibility of there being a break between the upper and the lower Merced which can not be accounted for merely by the depositional record.

The stratigraphic evidence that appears to suggest an unconformity in the Merced in the vicinity of Thornton Station has already been given on a preceding page. In addition to this we might add the faunal evidence in support of the unconformity. A short distance south of Thornton Station *Scutella interlineata* Stimpson, an extinct form, occurs abundantly. To the north of the station the fauna is almost entirely Recent. The space separating the two localities is hardly more than one quarter of a mile. The apparent break in the two faunas could be explained by having a space without a fauna, the deposition being continuous and the faunas changing by migration and extinction. The apparent discordance in the strata could be explained either by landslide or a fault as well as by unconformity. The evi-

dence is therefore not sufficient to establish a stratigraphic break at this locality.

The following fossils were collected by the writer from the Merced Series at its type locality. The terms upper and lower are used in connection with the fauna for correlation purposes. The lower Merced includes that portion of the series which occurs stratigraphically below the large landslide at Thornton Station. The upper Merced is that portion occurring above the landslide:

LIST OF FOSSILS FROM THE LOWER MERCED

Echinodermata	Gasteropoda
Scutella interlineata Stimpson	Amphissa, sp.
Scutella, n. sp.?	Astyris richthofeni Gabb
Pelecypoda	Bittium asperum Gabb
Arca trilineata Conrad	Calyptreaa radians Lamarek
Cardium meekianum Gabb	Calyptreaa filosa Gabb
Cardium quadrigenarium Conrad	Chrysodomus portolaensis (?)
Chione succincta Valenc.	Arnold
Cryptomya californica Conrad	Chrysodomus stantoni Arnold
Macoma inquinata Deshayes	Chrysodomus tabulatus Baird, var.
Macoma nasuta Conrad	colmaensis Martin
Marcia gibbosus Gabb	Crepidula grandis Midd.
Modiolus rectus Conrad	Crepidula onyx Sby.
Mya japonica Jay	Crepidula princeps Conrad
Nucula suprastrata Carpenter	Drillia inermis Hinds
Pandora grandis Dall	Drillia mercedensis Martin
Paphia staleyi Conrad	Neverita, sp.
Paphia staminea Conrad	Nassa moraniana Martin
Paphia staminea, var. diversa	Nassa mendica Gould
Sowerby	Natica clausa Brod. & Sby.
Paphia tenerrima Carpenter	Olivella biplicata Sby.
Pecten, sp.	Olivella pedroana Conrad
Phacoides annulatus Reeve	Pachypoma, sp.
Saxidomus giganteus Deshayes	Pisania fortis Carpenter
Schizothaerus nuttalli Conrad	Pisania fortis, var. angulata Arnold
Schizothaerus pajaroanus Conrad	Thais lamellosa Gmelin
Siliqua nuttalli Conrad	Thais lamellosa, var. septentrionalis
Solen sicarius Gould	Reeve
Spisula albaria Conrad	Thais lima Martyn
Spisula catilliformis Conrad	Tritonium, sp.
Tellina bodegensis Hinds	Cirripedia
Zirphaea gabbii Tryon	Balanus, sp.

The following list was obtained from the upper Merced north of Thornton Station:

Echinodermata	Paphia staminea Conrad
Echinarachnius excentricus Esch.	Saxidomus nuttalli Conrad
Pelecypoda	Transennella tantilla Gould
Cardium corbis Martyn	Gasteropoda
Cryptomya californica Conrad	Acanthina engonatum Conrad
Macoma inquinata Deshayes	Astyris californica Gaskoin
Macoma nasuta Conrad	Astyris gausapata, var. carinata
Mytilus edulis Linn.	Reeve
Ostrea lurida Carpenter	Cerithidae californica Hald.

Gasteropoda (*continued*)
Drillia inermis Hinds
Lacuna compacta Carpenter
Nassa fossata Gould
Nassa mendica Gould

Nassa mendica, var. *cooperi* Forbes
Natica clausa Brod. & Sby.
Olivella biplicata Sby.
Thais lima Martyn

MERCED OF BOLINAS BAY

A very limited area of Merced occurs immediately west of the entrance to Bolinas Bay, about twenty miles northwest of the type section at Seven Mile Beach. Along the cliffs south of the town of Bolinas the basal beds rest unconformably upon much disturbed strata of middle Miocene age. As at the type locality, the beds have been folded into a large monocline dipping eastward at an angle of approximately twenty degrees. The strike is north twenty to twenty-five degrees west. In lithological character the formation very closely resembles the series at Seven Mile Beach. Gray and light-brown fine-grained sandstones predominate, with a very small amount of clay and fine conglomerate. No accurate measurement of the thickness was attempted, but taking into consideration the small angle at which the beds dip and the limited area over which they occur, a conservative estimate would hardly place the thickness beyond five hundred feet.

A collection of fossil marine invertebrates made principally from the base of the section at Bolinas has revealed the occurrence of the following species:

Echinodermata
Scutella interlineata Stimpson
 Pelecypoda
Cardium meekianum Gabb
Macoma inquinata Deshayes
Macoma nasuta Conrad
Modiolus rectus Conrad
Paphia tenerrima Carpenter
Schizothaerus nuttalli Conrad
Spisula catilliformis Conrad
Spisula hemphilli Dall

Gasteropoda
Astyrus richthofeni Gabb
Drillia mercedensis Martin
Eplonium indianorum Carpenter
Nassa moraniana Martin
Nassa mendica Gould
Natica clausa Brod. & Sby.
Olivella biplicata Sby.
Olivella intorta Carpenter
Thais lamellosa Gmelin

All of these species, including the most characteristic, occur in the Merced Series at the type locality and show the close connection between the two sections.

MERCED OF AÑO NUEVO BAY

An area, similar to that at Bolinas Bay, occurs along the east shore of Año Nuevo Bay, about fifty miles south of the

Golden Gate. This area although very limited is of importance as it shows the relations between the Merced and the underlying Purisima. The two formations at this locality are conformable. The strata of both dip slightly toward the northeast, the strike being north and northwest. The beds consist of soft rusty-yellow and brownish-gray medium-grained sandstone with very small amounts of gravel and clay. In the upper horizon the soft material is interstratified with numerous hard calcareous layers which are abundantly fossiliferous. In the underlying Purisima the fossils are imbedded in concretions instead of in the calcareous layers as in the Merced. This is the most noticeable lithological difference between the two horizons, the greater portion of the sediments being similar in texture and color in the two sets of beds.

The following fossils, which were collected from the Merced horizon at Año Nuevo Bay, show the close connection with the beds at Seven Mile Beach:

Pelecypoda

Acila castrensis Hinds
Arca trilineata Conrad
Cardium meekianum Gabb
Cryptomya californica Conrad
Macoma nasuta Conrad
Marcia oregonensis Conrad
Modiolus rectus Conrad
Panomya ampla Dall
Panope generosa Gould
Paphia staleyi Gabb
Paphia tenerrima Carpenter
Solen sicarius Gould
Schizothaerus pajaroanus Conrad

Gasteropoda

Astyris richthofeni Gabb

Bathytoma carpenteriana Gabb

Chrysodomus stantoni Arnold

Crepidula grandis Midd.

Crepidula princeps Conrad

Drillia mercedensis Martin

Epitonium indianorum Carpenter

Margarita pupilla Gould

Nassa moraniana Martin

Nassa mendica Gould

Neverita, sp.

Olivella biplicata Sby.

Olivella intorta Carpenter

Olivella pedroana Conrad

Cirripedia

Balanus, sp.

MERCED OF PILLAR POINT

Another important outcrop of Merced occurs at Pillar Point in the extreme northwest corner of the Santa Cruz Quadrangle. Here the beds consist of dark-brown shale interbedded with coarse brown and gray medium-grained sandstone. The strata are tilted at various angles and show the results of considerable distortion. These beds appear to be connected, beneath the bay, with those exposed along the shore near the mouth of Purisima Creek. The lithological similarity suggests stratigraphic connection. The stratigraphic position of these beds suggests the possibility that they were at one time connected with the beds at Seven Mile Beach. If such

relations could be established definitely, it would aid materially in showing the close connection between the Merced Series and the Purisima Formation south of Halfmoon Bay.

The following species have been obtained from the Merced at Pillar Point:

Pelecypoda

Macoma, sp.

Pecten oweni Arnold

Phacoides annulatus Reeve

Siliqua nuttalli Conrad

Spisula albaria Conrad

Spisula hemphilli Dall

Gasteropoda

Astyris richthofeni Gabb

Thais lamellosa Gmelin

The presence of *Pecten oweni* Arnold in this fauna points toward a very close correlation between these beds and the Purisima Formation a few miles farther south. It would also indicate that they were slightly older than the beds at Seven Mile Beach, since *Pecten oweni* has not been found in that section. However, the absence of this form from closely related beds can hardly be taken as proof of a later age. It is the opinion of the writer that lateral distribution is an important factor in explaining the absence of such forms from certain formations. The character of the sea bottom, the geographic position of the basin of deposition, and numerous other factors might have been unfavorable for the maintenance of such characteristic species.

MERCED OF THE SARGENT OIL FIELD

In Santa Clara County, west and southwest of Sargent Station, there is an important occurrence of marine sediments, which contains a fauna similar to the upper Purisima and Merced formations along the coast. This formation has been called Merced and Purisima by Mr. William F. Jones in his account of the geology of this field. In the following discussion it will be referred to as the Merced for the reason that there are beds beneath which contain a number of species common to the lower Purisima which are not common to the Merced. It seems advisable therefore to use the name Merced in discussion of these beds.

The Merced of this region covers a number of separate areas, on both sides of the Pajaro River, and extending to the southeast for several miles. In some of these areas the structure is monoclinal, the strata dipping toward the east, while in others it is synclinal, as in the case of the large area one mile west of Sargent Station.

In all of the localities visited by the writer, these beds appeared to overlie conformably a formation which is closely related, faunally, to the Etchegoin of the Coalinga district, but which was called San Pablo by Jones. In reviewing the literature, on a previous page, it was pointed out that an unconformity had been reported by Jones between the Merced and this underlying San Pablo. The most careful observations made by the writer have not given us any evidence of a lithologic change between the beds referred to the San Pablo and the beds referred to the Merced, nor was any evidence of a stratigraphic break seen. The strata are composed of gray and brownish-gray, medium-grained sandstones with some clays and occasional seams of gravel.

The fauna from the upper horizon contains a number of forms common to the Etchegoin as well as to the Purisima and Merced formations. The percentage of living forms, however, is as great as in the Merced at Seven Mile Beach, and ten per cent greater than in the Purisima south of Halfmoon Bay. We are justified therefore, in correlating these beds with the Merced at the type locality.

The following species have been collected from the Merced of the Sargent Oil Field:

Pelecypoda	<i>Spisula falcata</i> Gould
<i>Acila castrensis</i> Hinds	<i>Spisula voyi</i> Gabb
<i>Arca canalis</i> Conrad	<i>Semele rubropicta</i> Dall
<i>Arca trilineata</i> Conrad	<i>Transennella californica</i> Arnold
<i>Cardium meekianum</i> Gabb	Gasteropoda
<i>Cryptomya ovalis</i> Conrad	<i>Astyris richthofeni</i> Gabb
<i>Cryptomya quadrata</i> Arnold	<i>Bittium asperum</i> Gabb
<i>Dosinia ponderosa</i> Gray	<i>Calyptrea filosa</i> Gabb
<i>Macoma nasuta</i> Conrad	<i>Cancellaria tritonidea</i> Gabb
<i>Mactra coalingensis</i> Arnold	<i>Drillia mercedensis</i> Martin
<i>Marcia oregonensis</i> Conrad	<i>Littorina scutulata</i> Gould
<i>Modiolus rectus</i> Conrad	<i>Neverita</i> , sp.
<i>Mytilus coalingensis</i> Arnold	<i>Nassa moraniana</i> Martin
<i>Pandora (Clidophora) punctata</i>	<i>Nassa mendica</i> Gould
Conrad	<i>Natica clausa</i> Brod. & Sby.
<i>Panope generosa</i> Gould	<i>Neverita reclusiana</i> Petit
<i>Paphia staleyii</i> Gabb	<i>Olivella biplicata</i> Sby.
<i>Paphia staminea</i> Conrad	<i>Olivella pedroana</i> Conrad
<i>Paphia tenerrima</i> Carpenter	<i>Thais canaliculata</i> Ducl.
<i>Schizothaerus nuttalli</i> Conrad	<i>Thais lamellosa</i> Gmelin
<i>Schizothaerus pajaroanus</i> Conrad	<i>Thais saxicola</i> Valenciennes
<i>Siliqua nuttalli</i> Conrad	Cirripedia
<i>Solen sicarius</i> Gould	<i>Balanus</i> , sp.
<i>Spisula albaria</i> Conrad	

MERCED OF THE SANTA ROSA VALLEY

The general stratigraphic, lithologic, and faunal relations of the Merced of the Santa Rosa Valley have been outlined in review-

ing the paper of Vance C. Osmont, who published the account of the geology of that region. The locality has not been visited by the writer and no additional evidence can be given. However the fauna known from these beds is sufficient to warrant its correlation with the Merced.

WILDCAT SERIES

PHYSICAL FEATURES

The Wildecat Series is typically represented in the south central part of Humboldt County, California, in the form of a monocline on the north slopes of Bear River Ridge, extending from the ocean eastward to Bryan's Rest. The strike of the strata is more or less parallel with the general course of Eel River, i. e., west or northwest. The beds are inclined toward the north at angles varying between fifteen and forty degrees. In a few cases the inclination is as great as seventy-five degrees, but these cases are rare, and dips greater than forty degrees are uncommon. A short excursion into the hills four miles northeast of Fortuna revealed the occurrence of marine sediments corresponding in age to the Wildecat Series. The rugged topography common throughout the region is characteristic of this formation and suggests that the territory covered by these beds is quite extensive. Later work may prove the occurrence of this series over a much greater portion of Humboldt County than it is now known to cover.

Beach Section.—As with the Merced Series, the beach section is most accessible and affords the best opportunity for study. At the mouth of Oil Creek, one mile north of Cape Fortunas, the basal beds, composed of rusty-yellow, shaly-structured, fine-grained sandstone, overlie a massive, coarse-grained, steel-gray sandstone which has been greatly fractured and folded. The latter is probably not later than Cretaceous and may possibly be Jurassic. Approximately half a mile farther north the rusty-yellow sandstone grades rather suddenly into gray and blue-gray argillaceous sandstone and clay. The material is soft and not well stratified, resembling very closely the lithological characters of the Merced. This gray and blue-gray sandstone with some variations continues northward to Centerville, where it dips beneath a brown beach sand and gravel lying in nearly horizontal position. The strike for the whole

section is approximately due west. The dip varies from thirty degrees at the base to fifteen degrees at the top of the section.

Ferndale Section.—Another excellent section for study was found along the Wildcat road which connects Ferndale with Capetown. On the north side of Bear River Ridge, about six and three-quarter miles south of Ferndale, the basal beds of the Wildcat Series were again found overlying the Mesozoic rocks, which form an important part of Bear River Ridge. In the lower portion of the section the series consist of rusty-yellow and light-brown shales which closely resemble some of the shale members of the Monterey Series in Contra Costa County. The shale gradually grades into a fine-grained sandstone still retaining the shaly structure. The thickness of these lower beds can hardly be more than six or seven hundred feet. No bedding planes are visible, so that the attitude of the strata and the thickness can not be measured accurately. The overlying strata have a dip of twenty to twenty-five degrees north. It is probable that these lower beds have approximately the same attitude. Overlying the basal beds is a gray, argillaceous, fine-grained sandstone which has a well-developed shaly structure. This member is probably of considerable thickness, as it outcrops along the roadside for several miles, and near the top, where the altitude was taken, the strike was found to be N 75° W, with a dip of twenty degrees to the north. Four and one-quarter miles south of Ferndale this member grades into a light-brown sandstone, which in turn grades into a massive gray sandstone. The latter is in the neighborhood of fifteen hundred feet in thickness, and on account of its massiveness is the most conspicuous member of the entire series. Three distinct beds of conglomerate outcrop above the massive gray sandstone, each being separated by fifty or more feet of coarse sandstone. The combined thickness of the conglomerate can hardly be less than two hundred feet. At the top of the exposed section brown sand and gravel overlie the conglomerate, which appears to dip beneath the Eel River Valley.

Alton Section.—A section along the west bank of the Eel River from Metropolitan to Alton, gave approximately the same results as the Ferndale section. Along the south bank of Eel River, south of Metropolitan, the beds consist of gray and rusty-yellow, fine-grained sandstone and clay. On following Howe Creek south toward its source, brown and reddish-brown shale was encount-

ered. In going north along the west bank of Eel River a considerable thickness of gray sandstone stained brown and greenish brown is met with. Farther north, at the mouth of Price Creek, a massive gray sandstone occurs. In lithologic character and thickness this member resembles very closely the massive gray member found in the upper portion of the Ferndale section. The uppermost strata of this section, along the west bank, have been removed by the river in forming the terrace on which the town of Grizzly Bluff is now situated. Fortunately, however, it is continued along the east bank north of Alton. Here the conglomerate outcrops and continues north toward Rohnerville. The top of the section, as at Ferndale, is composed of brown sand and gravel.

Scotia Section.—On the west bank of Eel River, near the mouth of Monument Creek, the Mesozoic rocks outcrop in a large mass just above the wagon road. The strike of this formation is due west with a south dip of seventy degrees. A short distance to the north a reddish-brown shale is exposed, having a strike of N 70° E, and dipping to the north at an angle of forty-five degrees. In continuing north the shale gradually changes to a lighter color and to a more sandy character. The strike also changes N 70° W. Several localities gave the same results and it seems probable that the attitude taken in the reddish-brown shale was measured in strata that had been slightly dislocated.

West of Scotia the light-brown shaly material is replaced by a massive light-brown sandstone. This member continues north for several hundred feet, where it gradually grades into brown shale and finally into a blue-gray argillaceous sandstone and clay. Beyond this point the section is not continued along the west side of the river, but is most remarkably exposed along the east side. Here the blue-gray sandstone and clay are followed by a brown and greenish-gray sandstone which contains a fauna somewhat similar to that found near the top of the upper Neocene at the mouth of Bear River, and also in the Alton section at a corresponding horizon. Blue and gray sandstones of considerable thickness are found next above the brown and greenish-gray material. In general, this member is composed of soft strata, but in some localities it has sufficient stability to form almost perpendicular cliffs three or four hundred feet in height. These cliffs are often referred to as the Scotia Bluffs. In this portion of the

section fossils are extremely abundant, often occurring in solid beds a foot or more in thickness. Beyond the Scotia Bluffs the beds enter a rugged and heavily timbered region where they could not be traced with accuracy. They undoubtedly extend northward to the Van Duzen River, where the uppermost part of the series should be found.

Shively Section.—Along the railroad track, one and one-half miles southeast of Shively, a very excellent section of strata was encountered. The base of the section, which is near the base of the series, consists of reddish-brown shale and light-brown shaly sandstone. The brown shale is overlaid by a blue-gray shale which grades into a coarse-grained gray sandstone. The latter is very fossiliferous and forms a prominent bluff on the north side of Eel River just below Bryan's Rest. The strike of the strata at this locality is N 75° W. The dip is toward the northeast at an angle of fifty degrees. One mile north of Shively the same horizon occurs as a prominent bluff on the east side of the river opposite the small town of Pepperwood. Here the strike is N 40° W, with a small east dip.

All of the sections here described have a close similarity with respect to the larger lithological divisions. We find in each case a similar sequence of beds. The lower portion in each section consists of rusty-yellow shales with light-brown and gray shaly sandstones. Overlying this is a series of gray and blue-gray sandstones with some clay shales. Toward the top the sandstone becomes coarse-grained and often conglomeratic. It is evident, therefore, from these sections that the Wildcat Series can be divided into two divisions on a lithologic basis—a lower member consisting of brown and rusty-yellow shales, followed by brownish-gray sandstone, and an upper member consisting of gray and blue-gray sandstone, with some clay shales and well cemented layers of sandstone, followed by coarse sandstone and conglomerate in some sections. In the Scotia section the division between the two members occurs about three-quarters of a mile north of the railroad station at Scotia. In the Alton section the division occurs on the south bank of the Eel River south of Metropolitan.

FAUNA OF THE WILDCAT SERIES

Taken as a whole, the Wildcat Series is one of the most fossiliferous Tertiary formations known along the coast of California.

Near the middle of the beach section, one-half mile north of the mouth of Guthrie Creek, several very good fossil localities are to be found. From this horizon as many as thirty species, principally small gasteropods, were obtained. The bluffs opposite Rio Dell contain the most abundant fauna of any locality that the writer has so far encountered. Some of the strata, a foot or more in thickness, are composed almost entirely of fossil invertebrates. Over fifty pounds of perfect specimens were collected in a part of one day from the central part of the section one mile north of Scotia.

One of the most noticeable characters of the fauna from the Wildcat Series is the division which can be made between the upper and lower portions, which agrees very closely with the lithologic divisions. The lower portion contains some species which are common to the Empire Formation of Coos Bay and other Miocene formations along the coast of California and Oregon. The upper portion contains a fauna quite similar to that of the Merced Series, and is very conspicuously boreal in character. The upper part of the lower division contains *Pecten dilleri* Dall, *Argobuccinum arnoldi* Martin, *Chrysodomus lawsoni* Martin, and numerous other species which are not found in the beds above. On the other hand, the upper division contains a large number of species which do not occur below. There is a distinct break in the fauna corresponding to the two lithologic divisions. If this series were to be divided between the Miocene and the Pliocene the separation would probably come between the two divisions that are indicated by the lithology and the fauna.

The following species were obtained by the writer from the lower division of the Wildcat Series:

Pelecypoda

Glycimeris, sp.
Macoma calcarea Gmelin.
Macoma nasuta Conrad
Pecten dilleri Dall
Pecten propatulus Conrad
Solemya ventricosa Conrad
Thyasira barbarensis Dall
Thyasira bisecta Conrad
Yoldia striagata Dall

Gasteropoda

Argobuccinum arnoldi Martin
Argobuccinum scotiaensis Martin
Chrysodomus andersoni Martin
Chrysodomus lawsoni Martin
Chrysodomus scotiaensis Martin
Chrysodomus eurekaensis Martin
Liomesus sulculatus Dall
Margarita condoni Dall
Solariella peromabilis Carpenter
Turris perversa Gabb
Turris cammani Dall

The following list of species were obtained from the upper division of the Wildcat Series:

Echinodermata	<i>Thracia trapezoidea</i> Conrad
<i>Scutella interlineata</i> Stimpson	<i>Venericardia castor</i> Dall
<i>Scutella</i> , n. sp.?	<i>Venericardia subtenta</i> Conrad
Pelecypoda	<i>Venericardia subtenta</i> , var. <i>quad-</i>
<i>Acila castrensis</i> Hinds	<i>rata</i> Conrad
<i>Acila conradi</i> Meek	<i>Yoldia striagata</i> Dall
<i>Cardium coosensis</i> Dall	Gasteropoda
<i>Cardium meekianum</i> Gabb	<i>Admete dilleri</i> Martin
<i>Chione securis</i> Shumard	<i>Argobuccinum oregonensis</i> Redfield
<i>Cryptomya ovalis</i> Conrad	<i>Astyris richthofeni</i> Gabb
<i>Kennerlia</i> , sp.	<i>Bela</i> , sp.
<i>Leda taphria</i> Dall	<i>Bela santae-monicae</i> Arnold
<i>Lyonsia californica</i> Conrad	<i>Bittium filosum</i> Gould
<i>Macoma calcaria</i> Gemlin	<i>Boreotrophon fleenerensis</i> Martin
<i>Macoma</i> , n. sp.	<i>Chrysodomus altispira</i> Gabb
<i>Macoma secta</i> Conrad	<i>Chrysodomus andersoni</i> Martin
<i>Macoma yoldiaformis</i> Carpenter	<i>Chrysodomus halibrectus</i> Dall
<i>Marcia oregonensis</i> Conrad	<i>Chrysodomus liratus</i> Martyn var.
<i>Modilus stalderi</i> Martin	<i>Chrysodomus rectirostris</i> Carpen-
<i>Mya japonica</i> Jay	<i>ter</i> , n. var.
<i>Nucula suprastrata</i> Carpenter	<i>Chrysodomus tabulatus</i> Baird
<i>Pandora grandis</i> Dall	<i>Drillia fleenerensis</i> Martin
<i>Panomya ampla</i> Dall	<i>Drillia inermis</i> Hinds
<i>Paphia staleyi</i> Gabb	<i>Drillia mercedensis</i> Martin
<i>Paphia staminea</i> Conrad	<i>Epitonium indianorum</i> Carpenter
<i>Pecten caurinus</i> Gould	<i>Mangilia</i> cf. <i>tabulatus</i> Carpenter
<i>Phacoides annulatus</i> Reeve	<i>Natica clausa</i> Brod. & Sby.
<i>Schizothaerus nuttalli</i> Conrad	<i>Natica</i> , near <i>lewisii</i> Gould
<i>Schizothaerus pajaroanus</i> Conrad	<i>Neverita recluziana</i> Petit
<i>Siliqua lucida</i> Conrad	<i>Olivella pedroana</i> Conrad
<i>Siliqua nuttalli</i> Conrad	<i>Taranis strongi</i> Arnold
<i>Solen sicarius</i> Gould	<i>Thais lamellosa</i> Gmelin
<i>Spisula albaria</i> Conrad	<i>Tritonofusus halli</i> Dall
<i>Spisula catilliformis</i> Conrad	<i>Trophon muriciformis</i> Dall
<i>Spisula voyi</i> Gabb	<i>Turris perversa</i> Gabb
<i>Tellina bodegensis</i> Hinds	

Nearly all of the forms included in the list from the lower horizon of the Wildcat Series, excepting the new species, occur in the Miocene of Coos Bay and other Miocene localities along the coast. It is probable, therefore, that the lower portion of the Wildcat Series is not later than the uppermost Miocene.

A large number of the species included in the list from the upper horizon have not previously been reported from this series. The list contains species that have been collected from all of the sections described on previous pages. A number of those obtained from the upper portion of the beach section, north of Guthrie Creek, occur commonly in the Pliocene of Santa Barbara and in the Pleistocene of San Pedro. This points toward a rather late Pliocene age for the uppermost portion of the beach section. The Scotia Bluffs, north of Scotia, yielded a fauna very similar to the Merced Series south of San Francisco, a fact which warrants a very close correlation between the two groups of beds.

UPPER MIOCENE OF BEAR RIVER

At the mouth of Bear River, Miocene and possibly Pliocene beds are to be found in the form of a synclinal fold. The section along the beach across this syncline extends for a mile on either side of the mouth of the river. On the north side of this area the basal beds rest unconformably upon a shaly portion of the Mesozoic formation which forms the headlands at Cape Fortunas and Cape Mendocino. These beds extend southward to within one mile of Cape Mendocino, where the basal portion is again found in contact with the Mesozoic rocks. The strata at this point dip northeast at an angle of thirty-five degrees. The strike is N 60° W. On the north side of the syncline the strike of the beds is N 50° W, and the dip is to the south at an angle of seventy degrees. The middle or axis of the syncline lies about half a mile south of the mouth of the river. The area covered by this formation extends only a short distance up the stream, and from a number of strikes and dips taken on either side of the river it appears to be a crescent-shaped area representing the extreme end of a syncline. In the lower portion the beds consist of fine-grained sandstones and shales which have buff and brownish-gray colors. Near the top of the section the strata consist of gray sandstone with thin layers of clay interstratified with it.

The determination of this formation as Miocene was made upon the finding of *Pecten peckhami* Gabb, and sharks' teeth in a small gulch a few hundred yards north of the mouth of Bear River. A small collection of fossils made from the upper horizon contained a number of species which are common to the Empire Formation on Coos Bay.

The following species were obtained from the upper portion of the upper Miocene formation at the mouth of Bear River:

Echinodermata	<i>Venericardia castor</i> Dall
<i>Schizaster stalderi</i> Weaver	Gasteropoda
Pelecypoda	<i>Argobuccinum arnoldi</i> Martin
<i>Chione</i> , sp.	<i>Chrysodomus bairdi</i> Dall
<i>Macoma calcarea</i> Gmelin	<i>Liomesus sulculatus</i> Dall
<i>Panope estrellana</i> Conrad	<i>Tritonofusus saundersi</i> Martin
<i>Phacoides acutilineata</i> Conrad	<i>Turris cammani</i> Dall
<i>Solemya ventricosa</i> Conrad	<i>Volutopsius eurekaensis</i> Martin

All of these species, excepting those listed as new forms, occur in the Empire Formation of the Oregon coast and it seems probable that the two formations were approximately contemporaneous in deposition.

Six miles east of Capetown, at the mouth of the south fork of Bear River, a small area of Miocene beds outcrops. These beds extend across the river to the north side where a small area is exposed. They consist of brown and gray sandstone. A few poorly preserved fossils were obtained, among them a species of *Pecten*, *Glycymeris conradi* Dall, and *Venericardia castor* Dall. It is probable that this small area was at one time connected with the beds at the mouth of Bear River.

PURISIMA FORMATION

Physical Features.—The rocks of the Purisima Formation occupy two geographically separate areas within the Santa Cruz Quadrangle, one on either side of the Santa Cruz Mountains. The one of greater importance occupies an area triangular in shape stretching from Halfmoon Bay southward along the coast to the mouth of Pescadero Creek, and then inward along Pescadero Creek to its source. The northeastern boundary of the area extends from the town of Halfmoon Bay southeast, more or less parallel to the main divide, to the mouth of Oil Creek. From this point the southern boundary follows Pescadero Creek northwest to Jones Gulch, where it turns due west for several miles, then turning southwest toward the town of Pescadero. The narrow strip extending south to Año Nuevo Bay is limited on the east by a prominent fault scarp along which movement took place, letting the Purisima down against the Monterey shale. On the west it is limited by outcrops of the Chico Formation on which the Purisima lies unconformably.

The area of Purisima thus outlined has been folded into a syncline whose axis lie approximately in the middle, extending southeast and northwest, conforming to the general structure of the region. The northeast wing of the syncline flanks the west slope of the Santa Cruz Range from Halfmoon Bay to Oil Creek, overlying probably unconformably Monterey shale, Vaqueros sandstone, and Tertiary diabase. The general strike is N 40° W, and the strata dip toward the southwest at an angle of twenty degrees. The southwest wing of the syncline has been distorted by faulting and has been partly submerged by the transgression of the sea. The beds dip to the north and northwest at low angles, usually not more than ten or twenty degrees. In some localities

the Purisima appears to rest conformably upon the Monterey shale and to grade into it; in other localities a marked lithological change marks the contact between the two formations.

The Purisima Formation is composed chiefly of sandstone. Whitish diatomaceous shales occur in some localities but they are relatively of small extent. The formation as described by Arnold and Haehl can be separated into three lithologic divisions: a lower sandstone, a middle shale, and an upper sandstone. The lower sandstone occurs most prominently along Pescadero Creek east of Jones Gulch and in the vicinity of La Honda. Here it attains a thickness of nearly three thousand feet. Conglomerate and coarse-grained sandstone occur at the base immediately overlying the Monterey shale. The upper portion of the lower member consists of soft gray and brown sandstones, occasionally grading into clay. The shale member extends over a wide area south and east of San Gregorio. Its thickness in this locality reaches approximately three thousand feet. In some respects it resembles the shales of the Monterey Series, varying from the pure diatomaceous shale to the impure clay shale. The upper sandstone covers an area approximately four miles in width extending along the coast from Halfmoon Bay to Pescadero Creek. It consists of light gray and brownish-gray fine-grained sandstone, usually soft and friable. Occasionally clay shale is interstratified with the fine-grained sandstone. The thickness of the Purisima Formation, as measured along Purisima Creek by Ralph Arnold, was approximately eight hundred feet.

The Purisima occurring on the east side of the Santa Cruz Mountains, southwest of Stanford University, consists of soft quartzose sandstone. Near the base of the section, which is hardly more than three hundred feet in thickness, the beds contain numerous barnacles (*Balanus concavus* Bronn). The lime from the barnacles has greatly hardened the sandstone, according to Arnold and Haehl, who described this series. The fauna from these beds appears to represent a lower horizon than the Purisima along the west side of the Santa Cruz Range.

Fauna.—The Purisima Formation is not extremely fossiliferous, although a few localities have afforded a large number of species. The middle and lower members have yielded only a few species that are determinable, and these are forms which have a comparatively long life-period.

The following species were obtained from the upper standstone member of the Purisima Formation, chiefly from the sea-cliffs south of Halfmoon Bay:

Echinodermata	Solen sicarius Gould
Echinarachnius gibbsii Rémond	Spisula albaria Conrad
Scutella interlineata Stimpson	Spisula catilliformis Conrad
Scutella perrini Weaver	Spisula hemphilli Dall
Pelecypoda	Thracia trapezoidea Conrad
Acila castrensis Hinds	Yoldia cooperi Gabb
Acila rectus Conrad	Zirphaea gabbii Tryon
Arca canalis Conrad	Gasteropoda
Arca trilineata Conrad	Argobuccinum oregonensis Redfield
Cardium meekianum Gabb	Astyris richthofeni Gabb
Clidiophora punctata Conrad	Bathytoma carpenteriana Gabb
Cryptomya californica Conrad	Bittium asperum Gabb
Cryptomya ovalis Conrad	Calyptrea filosa Gabb
Dosinia ponderosa Gray	Calyptrea inornata Gabb
Leda taphria Dall	Chrysodomus liratus Martyn
Macoma calcarea Gmelin	Chrysodomus portolaensis Arnold
Macoma inquinata Deshayes	Chrysodomus purisimaensis Martin
Macoma nasuta Conrad	Chrysodomus stantoni Arnold
Marcia oregonensis Conrad	Chrysodomus tabulatus Baird
Panomya ampla Dall	Crepidula, cf. onyx Sby.
Panope generosa Gould	Crepidula princeps Conrad
Paphia staleyi Gabb	Drillia mercedensis Martin
Paphia tenerrima Carpenter	Miopleiona oregonensis Dall
Pecten healeyi Arnold	Nassa moraniana Martin
Pecten nutteri Arnold	Nassa mendica Gould
Pecten oweni Arnold	Natica lewisii Gould
Pecten purisimaensis Arnold	Natica clausa Brod. & Sby.
Phacoides annulatus Reeve	Thais lamellosa Gmelin
Schizothaerus nuttalli Conrad	Cirripedia
Schizothaerus pajaroanus Conrad	Balanus, sp.
Siliqua nuttalli Conrad	

This list contains a few forms, such as *Pecten healeyi* Arnold, and *Pecten purisimaensis* Arnold, which are supposed to be characteristic of the Pliocene, and have not so far been reported from the Merced Series at the type locality. This, together with the fact that certain supposedly Miocene forms, *Pecten oweni* Arnold, *Pecten nutteri* Arnold, and *Echinarachnius gibbsii* Rémond, occurred in this formation, was the basis upon which Arnold and Haehl separated these beds from the Merced Series and applied the new name Purisima Formation. The presence of a number of the larger pectens has caused some palaeontologists to place the beds as intermediate between the Pliocene and Miocene, and still others to place them entirely within the Miocene. It is a well-recognized fact that the division between the Miocene and Pliocene in California is not well marked in any of the formations, and any separation attempted, outside of that suggested by the faunas, is more or less arbitrary. It is not the object of this paper to make an accurate age determination, but

rather to show the relations between the various formations considered. It is the opinion of the writer that the Purisima Formation is the equivalent of a part of the Etchegoin and the lower portion of the Merced Series at Seven Mile Beach.

ETCHEGOIN OF THE SARGENT OIL FIELD

Unconformably overlying the Monterey shales of the Sargent Oil Field there is a formation composed of conglomerates, coarse and fine-grained sandstones, and shales which was correlated by William F. Jones with the San Pablo Formation of the Mount Diablo region. The basis on which the correlation was made was the occurrence of vivianitic sandstone. Jones separated this member into five lithologic divisions; A, the lowest member, consisted of conglomerate and coarse brown sandstone; B and C were composed of gradational series of light azure blue sandstones, quite coarse at the base and grading into shale at the top; D consisted of fine and medium-grained sandstone; E, the uppermost of the series, consisted of coarse and brown sandstones. All of these members are conformable and belong to one formation. The separation was doubtless made to bring out more strongly the lithological variation within the formation.

The territory covered by these beds comprises several small areas a short distance west and northwest of Sargent Station. The largest of these areas have been folded into an anticline and a syncline. The axes of these folds extend from the southwest toward the northeast. Both are parallel to La Brea Creek, one on either side, the anticline on the north and the syncline on the south. These beds grade upward into the Merced horizon which conformably overlies them.

Fauna.—The correlation of these beds with the San Pablo Formation was made by Jones upon a lithologic similarity, the occurrence of the vivianitic sandstone. Recent collecting in this horizon has brought out some rather interesting faunal relations. The San Pablo of this region has a very close faunal relationship to the Etchegoin of the Coalinga district, very much closer than with the San Pablo at the type locality. This is shown in two ways: (1) Of the forty species obtained from the San Pablo in the Sargent Oil Field nearly all occur in the Etchegoin while only sixteen occur in the San Pablo near Mount Diablo, and these have a very wide vertical and horizontal range; (2) The species that are most char-

acteristic of the Etchegoin, such as *Echinarachnius gibbsii* Rémond, *Pecten watsii* Arnold, and *Pecten nutteri* Arnold, occur in the Sargent section and do not occur in the region of Mount Diablo. It seems, therefore, that we are justified in assigning the beds previously known as San Pablo, in the Sargent Oil Field, to the Etchegoin Formation.

The following species were collected by the writer from the Etchegoin of the Sargent Oil Field:

Echinodermata	<i>Pecten watsii</i> Arnold
<i>Echinarachnius gibbsii</i> Rémond	<i>Pecten watsi</i> , var. <i>etchegoini</i> Anderson.
Pelecypoda	<i>Phacoides annulatus</i> Reeve
<i>Arca trilineata</i> Conrad	<i>Saxidomus nuttalli</i> Conrad
<i>Cardium meekianum</i> Gabb	<i>Schizothaerus nuttalli</i> Conrad
<i>Chione securis</i> Shumard	<i>Schizothaerus pajaroanus</i> Conrad
<i>Cryptomya quadrata</i> Arnold	<i>Siliqua nuttalli</i> Conrad
<i>Glycimeris coalingensis</i> Arnold	<i>Solen sicarius</i> Gould
<i>Macoma indentata</i> Carpenter	<i>Spisula albaria</i> Conrad
<i>Macoma inquinata</i> Deshayes	<i>Thracia</i> , sp.
<i>Macoma nasuta</i> Conrad	<i>Yoldia cooperi</i> Gabb
<i>Macoma secta</i> Conrad	<i>Zirphaea gabbi</i> Tryon
<i>Mya japonica</i> Jay	Gasteropoda
<i>Mytilus coalingensis</i> Arnold	<i>Calyptrea filosa</i> Gabb
<i>Ostrea atwoodi</i> Gabb	<i>Chrysodomus portolaensis</i> Arnold
<i>Panomya ampla</i> Dall	<i>Crepidula princeps</i> Conrad
<i>Panope generosa</i> Gould	<i>Nassa fossata</i> Gould
<i>Paphia staleyi</i> Gabb	<i>Natica</i> , n. sp.
<i>Paphia staminea</i> Conrad	<i>Natica reclusiana</i> Petit
<i>Paphia staminea</i> , var. <i>orbella</i> Carpenter	<i>Thais kettlemanensis</i> Arnold
<i>Pecten nutteri</i> Arnold	Cirripedia
<i>Pecten oweni</i> Arnold	<i>Balanus</i> , sp.

LATER NEOCENE AND QUARTERNARY DEPOSITS OF CAPE BLANCO, OREGON

At Cape Blanco, Oregon, about fifty miles north of the California boundary, there are marine sediments which are closely related to the later Pliocene formations of the California coast. In order to point out these relations the geology and palaeontology of this region will be briefly outlined.

The formations concerned in the geology of this locality include the Myrtle Formation, the Empire Formation, the Elk River Beds, and a terrace formation which may be later than the Elk River Beds. The oldest rocks are those of the Myrtle Formation, considered by Diller, who described the formation, to be of Cretaceous age. Strata of this formation outcrop along the cliffs from Cape Blanco northward to Blacklock Point. They also occupy a very small area immediately south of the Cape. Farther inland the Myrtle Formation is

of widespread occurrence. The Empire Formation, of middle Miocene age, unconformably overlies the Myrtle Formation. The rocks of this series occupy two separate areas. The strata of one of these areas outcrop along the ocean cliffs from Cape Blanco to a small gulch one and one-half miles southeast, where they are unconformably overlaid by later deposits. The other area outcrops along the cliffs north of Blacklock Point to Floras Lake. Diller in mapping this region considered that the Empire Formation extended continuously from Cape Blanco to the mouth of Elk River, a distance of two and one-half miles. This was an error, as will be shown later by palaeontological evidence. The strata of this area dip with a uniform inclination from Cape Blanco southeast to the small gulch already referred to. The lower members are composed of a yellowish-gray sandstone. Above this there is a layer of tuff which is about twenty feet in thickness. This tuff contains numerous leaf impressions. The upper portion consists of whitish and yellow sandstone, medium to fine-grained. A collection of fossils from these beds warrants their correlation with the Empire Formation of Coos Bay. Diller designated this formation as the Cape Blanco Beds.

Immediately north of the small gulch, one and one-half miles southeast of Cape Blanco, the uppermost strata of the Cape Blanco Beds are unconformably overlain by a thick bed of conglomerate which grades upward into a coarse brown sandstone, and finally into blue-gray argillaceous sandstone. South of this gulch the cliffs afford a complete section to the mouth of Elk River. The beds exposed in this section can be separated lithologically into two divisions: (1) a blue-gray argillaceous sandstone or mudstone which is the same member as was found overlying the conglomerate on the north side of the gulch; (2) a loose gray sand which is very similar to the sand of the Upper San Pedro Series at San Pedro, California. These two members extend the entire length of the section from the gulch to the mouth of Elk River, where they dip beneath the beach sand. The blue-gray argillaceous sandstone forms the base of the cliffs for the entire distance. The loose gray sand overlies it conformably, both dipping at a very small angle to the south and east. The difference between these two members is most noticeable in the face of the cliff. The lower beds are consolidated and form a vertical wall twenty or thirty feet in height. The overlying loose sand yields easily to weathering and as a result a distinct angulation occurs in the face of the cliff at this point.

Near the mouth of Elk River both of these horizons are very fossiliferous. In the lower beds the fossils occur in numerous hard concretions, while in the overlying sands they occur in a thick mass as an unconsolidated shell bed. The faunas are sufficiently distinct to allow the series to be separated into two horizons, although they are not separated by a stratigraphic break. From the great number of Recent species found in the upper horizon it seems certain that it is very closely related to the Upper San Pedro Series, at San Pedro, and is at least Pleistocene in age. The underlying beds also contain a large number of Recent forms, but they likewise contain a large number of species that are common to the Merced and the Wildcat Series, and it is not improbable that this lower horizon represents very late Pliocene and is to be correlated with the uppermost part of the Wildcat Series.

Along the summit of the cliff one quarter of a mile southeast of Cape Blanco there is a formation of gray sand, mudstone, and gravel lying horizontally across the tilted edges of the Empire Formation. At the base of this deposit there is a fossil bed containing fifteen or twenty species, all of which appear to be Recent. A number of these are species of clams which bury themselves in the mud, such as *Schizothaerus nuttalli* Conrad. These fossils are, at the present time, imbedded in the uppermost part of the Empire Beds instead of the more recent deposit. This formation is hardly more than ten or fifteen feet in thickness and is overlain by three or four feet of soil. Diller considered these beds to be a part of the Pleistocene deposits at the mouth of Elk River, the Elk River Beds. There are a few species in each of these localities which are not common to both. The difference in the faunas may be due to the difference in position with regard to the strand line. The formation at the top of the cliff near Cape Blanco was undoubtedly deposited after the coastal plain had been formed, and just previous to its uprising. It is probable that the major part of the Elk River Beds were deposited during the period in which the coastal plain was forming, and in this way the beds at the mouth of Elk River would antedate the formation unconformably overlying the Empire Formation near Cape Blanco.

CORRELATION

The physical features of the formations, with which we are dealing, have been briefly outlined, and complete faunal lists from all of

them have been brought together, we therefore are in a position to sum up the evidence and work out the faunal relations which exist among all of these formations. In general there are two methods on which faunal correlations are based: (1) the use of characteristic species; (2) the percentage method. The latter may include the percentage of species common among the formations themselves as well as the percentage of living species common to the formations. In the present work it seems advisable to use all the methods available in order to obtain as nearly perfect results as possible.

In applying the percentage method a system of tables has been constructed which shows in numerical values the approximate relation among the formation or portions of formations. The first table (table 1), shows the occurrence of all of the species that were obtained from all of the formations which have been considered in this investigation. Table 2 shows in numerical values the number of living species found in each formation, and also the number of species common to all of the formations among themselves. To show this in tabulated form, all of the formations are arranged as ordinates and also as abscissae. The square space opposite any two of these formations, which are arranged normal to each other, contains the number of species common to both of those formations. It is evident that the number of species from the different formations varies considerably, and since this is the case the magnitude of the number itself can not be taken as a direct index of the relation between the formations. The percentage of species common to the formations compared will not vary directly as the number of species. Table 3 has been constructed to show this percentage and also the percentage of living species common to the formations. There are two percentages to be taken into consideration; the percentage of the species in *A* that is common to *B*, and the percentage of the species in *B* that is common to *A*. It is certain that these percentages will usually be different, since there is, in most cases, a greater number of species in one formation than in the other. For our purpose in correlating, these percentages can be added and used as a factor. The magnitude of this factor will indicate the approximate relation between any two formations: that is, if the combined percentages of the species common to *A* and *B* is greater than the combined percentages of the species common to *B* and *C*, it will indicate that *A* and *B* are more closely related than *B* and *C*.

There are a few sources of error which will affect the results

very greatly unless they are eliminated. A small number of species from one formation will change the factors considerably. It is necessary therefore to have a large number of species from all of the formations which are to be considered. Geographical separation also affects the results very noticeably. Formations that are widely separated will have a smaller number of species in common than formations that are not so situated.

With our data tabulated as in the following tables, and with the possibility of errors in mind, we can readily construct a correlation table which will show the relations of each formation as worked out by the percentage method. Turning to table 3 we find in the first column, reading from top to bottom, the percentage of living forms. The formation having the greater per cent of living species will, of course, be the most recent. Those having the same percentage of living forms will be approximately contemporaneous in deposition. Considering then the percentage of living species we find that the upper Merced is very recent, certainly Pleistocene. The Merced of Bolinas Bay, of Año Nuevo Bay, of Seven Mile Beach, of Pillar Point, and of Sargent Oil Field are all of the same age and are very closely related to the upper Wildecat and to the Purisima. The Etchegoin of the Sargent Oil Field, the lower Wildecat, and the so called Miocene of Bear River are older.

Taking now the factors representing the percentage of species common to the formation among themselves, we find that a similar relation will work out. Comparing the formations to the upper Wildecat we find that the largest factors correspond to the Merced of Seven Mile Beach and to the Merced of Sargent Oil Field. If we compare the formations to the Etchegoin of the Sargent Oil Field we find that the Purisima is more closely related to it than the Merced or the Wildecat Series. By comparing each of the formations in this manner a relation would be worked out which would agree very closely with that shown in the column of the percentages of living species.

In correlating by means of the most characteristic species we find that the Etchegoin of the Sargent Oil Field contains a number of the short-lived forms which occur abundantly in the Etchegoin of the Coalinga district. We are justified, therefore, in correlating these formations and assigning them to the same horizon. A few of the short-range species of the Etchegoin fauna occur commonly in the Purisima, and it seems probable that a portion of the Purisima

is equivalent to a portion of the Etehegoin, and cannot be distinctly separated from it as suggested by Dr. J. P. Smith. Whether the whole Purisima Formation is equivalent to the Etehegoin cannot at present be definitely settled, because the fauna of the lower Purisima is rather meager and is not sufficiently characteristic.

The Merced Series, the upper portion of the Purisima, and the upper Wildcat contain a number of short-lived species in common and it is evident that they are approximately equivalent. The Merced Series and the upper Wildcat are certainly contemporaneous, and the lower portions of these two formations are not far removed from the uppermost Purisima.

The lower Wildcat and the so-called "Miocene of Bear River" have a few species in common which are not found above these horizons. They also contain species which occur abundantly in the Empire Formation of Coos Bay. From this evidence it seems probable that the lower Wildcat and the "Miocene of Bear River" belong to a lower horizon than the typical Merced and follow the Empire Formation very closely in the order of deposition.

From the superposition of beds similar in age it is probable that the lower Wildcat and the "Miocene of Bear River" are closely related to the Etehegoin and a portion of the Purisima Formation.

Transmitted June 16, 1914.

TABLE I
FAUNA OF THE PLIOCENE OF MIDDLE AND NORTHERN CALIFORNIA

	Elchegeoin, Sargent	Bear River Miocene (?)	Lower Wildcat	Purisima	Lower Merced	Middle Wildcat	Merced, Sargent	Merced, Bolinas Bay	Merced, Año Nuevo Bay	Merced, Pillar Point	Upper Merced	Living
ECHINODERMATA												
Echinarachnius excentricus Esch.												
Echinarachnius gibbsii Rémond	x			x	x						x	
Schizaster stalderi Weaver		x				x						
Scutella interlineata Stimpson				x				x				
Scutella perrini Weaver				x								
PELECYPODA												
Acila castrensis Hinds				x					x			
Acila conradi Meek						x						
Arca canalis Conrad				x			x					
Arca trilineata Conrad	x			x	x		x					
Cardium coosensis Dall						x						
Cardium corbis Martyn												
Cardium meekianum Gabb	x			x	x		x				x	
Cardium quadrigenarium Conrad					x							
Chione securis Shumard	x					x						
Chione succincta Valen.												
Chione, sp.		x				x						
Cryptomya californica Conrad				x	x				x		x	
Cryptomya, cf. ovalis Conrad				x		x						

[illegible]

TABLE I (Continued)

GASTROPODA (Continued)	Etchegoien, Sargent	Bear River Miocene (?)	Lower Wildcat	Purisima	Lower Merced	Middle Wildcat	Merced, Sargent	Merced, Bolinas Bay	Merced, Año Nuevo Bay	Merced, Pillar Point	Upper Merced	Living
Chrysodomus andersoni Martin	×	×
Chrysodomus bairdii Dall.....	×
Chrysodomus eurekaensis Martin	×
Chrysodomus halibrectus Dall.....	×
Chrysodomus lawsoni Martin	×
Chrysodomus liratus Martyn.....	×	×	×
Chrysodomus portolaensis Arnold.....	×	×	×
Chrysodomus purismaensis Martin	×
Chrysodomus rectirostris Cpr.	×
Chrysodomus scotiaensis Martin	×
Chrysodomus stantoni Arnold.....	×	×	×
Chrysodomus tabulatus Baird.....	×	×
Columbella (Astyris) californica Gaskoin.....	×	×
Columbella (Astyris) gausapata Gould.....	×
Columbella (Astyris) gausapata, var. carinata Reeve	×	×
Columbella (Astyris) richthofeni Gabb.....	×	×	×	×	×	×
Crepidula grandis Midd.	×	×
Crepidula onyx Sby.	×	×
Crepidula princeps Conrad.....	×
Drillia fleenerensis Martin.....	×

[illegible]

TABLE 2
CORRELATION TABLE OF THE PLIOCENE FORMATIONS OF MIDDLE CALIFORNIA¹⁹

	Living	Upper Merced	Merced, Bolinas Bay	Merced, Año Nuevo Bay	Lower Merced, Type Locality	Merced, Sargent Oil Field	Merced, Pillar Point	Upper Wildcat	Purisima	Etchegoin, Sargent	Lower Wildcat	Bear River Miocene (?)
Living												
Upper Merced.....	22	22	...	...	...	...	...	...	...	...	...	...
Merced, Bolinas Bay.....	15	6	19	...	...	...	...	...	...	...	...	...
Merced, Año Nuevo Bay.....	18	5	12	29	...	...	...	...	...	...	...	...
Lower Merced, Type Locality....	29	11	16	24	57	...	...	...	...	...	...	...
Merced, Sargent Oil Field.....	26	7	14	17	24	44	...	...	...	...	...	...
Merced, Pillar Point.....	3	0	3	3	6	5	8	...	...	...	...	...
Upper Wildcat	39	3	8	13	24	19	4	66	...	...	...	...
Purisima	28	6	14	21	32	25	7	25	60	...	...	...
Etchegoin, Sargent	18	5	4	9	18	16	3	15	23	41	...	...
Lower Wildcat	4	1	1	1	1	1	0	4	3	1	20	...
Bear River Miocene (?).....	1	0	0	0	0	1	0	3	2	1	5	11

TABLE 3

	Living	Upper Merced	Merced, Bolinas Bay	Merced, Año Nuevo Bay	Lower Merced, Type Locality	Merced, Sargent Oil Field	Merced, Pillar Point	Upper Wildcat	Purisima	Etchegoin, Sargent	Lower Wildcat	Bear River Miocene (?)
Living												
Upper Merced	100	...	...	...	...	...	...	...	...	...	...	...
Merced, Bolinas Bay.....	79	59	...	...	...	...	...	...	...	...	...	...
Merced Año Nuevo Bay.....	62	39	104	...	...	...	...	...	...	...	...	...
Lower Merced, Type Locality....	50	70	112	122	...	...	...	...	...	...	...	...
Merced Sargent Oil Field.....	59	48	106	97	97	...	...	...	...	...	...	...
Merced, Pillar Point.....	47	0	54	48	85	74	...	...	...	...	...	...
Upper Wildcat	59	18	54	64	78	72	56	...	...	...	...	...
Purisima Formation	47	37	97	107	109	99	99	83	...	...	...	...
Etchegoin, Sargent	44	35	31	53	76	75	45	59	94	...	...	...
Lower Wildcat	9	9	10	8	7	7	0	26	20	7	...	...
Bear River Miocene (?).....	0	0	0	0	0	0	0	31	21	11	70	...

¹⁹ See description of Table 2 and Table 3 on page 248.

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MESOZOIC AND CENOZOIC MACTRINAE
OF THE PACIFIC COAST OF
NORTH AMERICA

BY

EARL L. PACKARD

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INTRODUCTION

Although a considerable number of species belonging to the subfamily Mactrinae have been described from the Pacific Coast region of North America, the taxonomy and the phylogeny of the group have been but imperfectly understood. The existing situation is due largely to great individual variation in the superficial specific characters of the shell. As a consequence of our lack of understanding of the group, there has been much confusion regarding the geologic range of certain mactrine species.

It is the purpose of this paper to apply the taxonomic system proposed by Dr. W. H. Dall to the West Coast mactrine species, to record the known variation found within each species of this subfamily, to discuss the geologic and geographic ranges of the different species, to determine the value of each species to the stratigraphic geologist, and incidentally to describe several forms that are apparently new to science.

The term Pacific Coast region as used above is intended to include only the territory from Mexico northward to the coast of Alaska, and extending eastward to the Sierra Nevada and the Cascade mountains.

A large number of fossil and living Mactrinae belonging to the University of California and the University of Washington have been available for study. These collections include several types of species and varieties.

The writer wishes to express his thanks to Dr. John C. Merriam for the general supervision of this paper; and to Dr. Charles E. Weaver of the University of Washington, who loaned several type specimens and gave much valuable assistance during the early stages of this study.

HISTORICAL SKETCH

During the period in which the West Coast species were described the basis of classification of the Pelecypoda changed considerably. Gray¹ in his study of the Mactridae, in 1837, differed from his predecessors in that he based his classification largely upon the position of the ligament, whereas the earlier naturalists had considered the general shape, the pallial line, or some minor anatomical character as having the largest taxonomic value. Gray's system, modified by such workers as Reeve², Conrad, and Gabb, was in general use until Dall³ in 1889 demonstrated the value of the pelecypod hinge as a basis of classification. Subsequent investigators have accepted Dall's conclusions and have successfully applied his methods in the separation of the subordinate groups of the Pelecypoda.

¹ See Deshayes, G. P., *Traite elementaire de conchyliologie*, tom. 1, pt. 2, p. 256, et seq., 1843-1850.

² Reeve, L. A., *Conchologia Iconica*, "Monograph of the Genus Mactra," vol. 8, 21 pls., April 1, 1854.

³ Dall, W. H., On the hinge of the Pelecypoda and its development, etc., *Amer. Jour. Sci.* (3), vol. 38, pp. 445-462, 1889.

The first mactrine species reported from the Pacific Coast region of North America was *Mactra californica*⁴, described by Conrad in 1837 from Santa Barbara, California. Other species were subsequently described by the same author in various papers, the last of which appeared in 1867; his list of species is completed by the following: *Mactra albaria*, *M. catilliformis*, *M. diegoana*, *M. planulata*, *Mactra* (?) *gabiotensis*, *Mulinia densata* and *Spisula dolabriformis*. Conrad⁵ also contributed in 1867 a synopsis of the Mactridae in which he designated a typical species for each of his taxonomic groups. Gray in the latter part of 1837 defined the superfamily Mactracea, the family Mactridae and several genera as now recognized. Among his new species a West Coast form appears under the name of *Mactra exoleta*.

During 1848-50 Gould described *Mactra falcata* and *M. nasuta*, and Meek reported in 1861 the new species, *M. gibbsana*, which he obtained in a boulder of doubtful Cretaceous age, from the Straits of Juan de Fuca. Rémond described a *Mulinia* in 1863 under the name *Cardium gabbii*, which later became the type of Gabb's genus *Pseudocardium*.

Gabb described in 1869 the genus *Cymbophora*, the typical species of which he had previously named *Mactra ashburnerii*. His new mactrine species include: *Callista voyi*, *Hemimactra lenticularis*, *Hemimactra* (?) *occidentalis*, *Lutraria truncata*, *Mactra ashburnerii*, *Mactra* (?) *tenuissima* and *Schizodesma abscissa*.

The eastern species *Mactra warrenana* Meek was reported by Whiteaves from the Cretaceous of the San Juan Islands, Washington, but later it was referred by the same author to one of Gabb's West Coast forms.

Dr. W. H. Dall made the next contribution to the knowledge of the West Coast Mactridae, when in 1894 he published a synopsis of both the East and West Coast species⁶. This was amplified during the following year⁷, and again later in the *Transactions* of the

⁴ References to the original descriptions of the species mentioned in this section may be found under the headings of the species in question in the systematic portion of this paper.

⁵ Conrad, T. A., Catalogue of the Family Mactridae, Amer. Jour. Conch., vol. 3, appendix, pp. 30-47, 1868.

⁶ Dall, W. H., Synopsis of the Mactridae of northwest America, south to Panama, Nautilus, vol. 8, pp. 25-28, and pp. 39-43, 1894.

⁷ Dall, W. H., Synopsis of a review of the genera of Recent and Tertiary Mactridae and Mesodesmatidae, Proc. Mal. Soc. London, vol. 1, pp. 203-213, 1895.

Wagner Free Institute of Science⁸. These last two papers contain excellent definitions of the genera, subgenera and sections into which the family had been divided previously. The many cuts of the last paper showing the important taxonomic characters of the different groups add much to the usefulness of the paper. Between the years 1894 and 1909, Dall described the following: *Mactra hemphilli*, *Mulinia oregonensis*, *Spisula alaskana*, *S. callistaeformis* and *S. precursor*.

In the meantime F. M. Anderson described *Mactra gabbiana*, and Dr. Ralph Arnold added the following: *Mactra coalingensis*, *M. montereyana*, *M. stantoni*, *Mulinia densata* var. *minor*, *Spisula catilliformis* var. *alcatazensis* and *S. sisquocensis*.

Dr. C. E. Weaver in 1912 reported the following from the Miocene of Washington: *Pseudocardium landesi*, *P. gabbi* var. *altum*, *P. gabbi* var. *elongatum*, *P. gabbi* var. *robustum* and *P. gabbi* var. *unduliferum*.

BASIS OF CLASSIFICATION

Certain shell characters that are now considered of taxonomic value were omitted in the early descriptions of the West Coast Mactrinae, because systematists did not regard them as of importance. The shell characters such as general shape, or position of the umbones, which were considered by these earlier writers are now known to be too variable to be of much value to the systematist. A number of Conrad's mactrine species were based upon specimens too immature for specific determination. This was recognized by Carpenter, who in speaking of Conrad's early descriptions, says: "Conrad's types being lost, and his species imperfectly described from very young specimens, a difficulty attends their identification."⁹

In reviewing the mactrine species it has been found necessary to apply a standard to each described form. A study of the specific variations within this subfamily has revealed the fact that the most constant shell characters within a species are those dependent upon the dentition. Dall was the first to recognize the value of the hinge of the Mactridae as a satisfactory basis of classification. He provided a special nomenclature for the hinge dentition of these forms in his

⁸ Dall, W. H., Mactridae, Transactions Wagner Inst. Sci., vol. 3, pt. 4, pp. 862-891, 1898.

⁹ Carpenter, P. P., Brit. Assn. Rept. 1863, p. 99.

articles upon this family published in the *Proceedings* of the Malacological Society of London,¹⁰ and in the *Transactions* of the Wagner Free Institute of Science.¹¹

The mactroid hinge consists of a \wedge -shaped cardinal tooth, situated just anterior to the resilifer, and an anterior and a posterior lateral in the left valve, which fit between two laterals, or laminae, in the right valve. The cardinal of the left valve is formed of two parts, an anterior and a posterior arm. These arise from the hinge plate and are fused along a dorsal median line. The posterior arm often supports, at its base, a secondary process, which may overhang the pit or chondophore, and may extend parallel to the arm of the cardinal to a height equal to that of the cardinal itself. This accessory lamella is strongly developed in the lutrarine species *Schizothaerus nuttallii* (Conrad). This may be clearly seen in the figure of that species found on plate 35. Other lamellae occur upon the laterals of certain species, notably upon those of *Mactra californica*. The cardinal of the right valve differs considerably from that of the left. The more diverging arms of this tooth fit outside those of the left cardinal of the opposite valve. In the right cardinal the arms are often unequally developed. In the case of those species belonging to the subgenus *Cymbophora* the posterior arm is entirely absent, while other subgenera are characterized by having the cardinal arms of nearly equal development. *Mactra exoleta* is a good example of such a form. Furthermore the cardinal arms are seldom united along a median line as is the case in the left valve, but are slightly separated and joined to the dorsal margin of the shell.

The resilium and the ligament bear a varied relation to each other and serve, therefore, as important bases for generic definitions. In the genus *Mactra* the two are separated by a shelly ridge which extends ventrally from the beak. This fragile partition is but imperfectly seen in many of the typical mactroid species. It is represented in the left valve of *Mactra exoleta* by a low ridge extending from a point under the beaks to the ventral-posterior margin of the resilifer. A condition that is somewhat comparable is seen in the lutrarine species *Schizothaerus nuttallii*. In the genus *Spisula* the resilium and the ligament are not separated by any limiting wall

¹⁰ Dall, W. H., Proc. Mal. Soc. London, vol. 1, pp. 203-213, 1895.

¹¹ Dall, W. H., Trans. Wagner Institute Sci., vol. 3, pt. 4, pp. 862-891, 1898.

of shell. In *Mulinia* the union of these elements is even more intimate, since they are completely submerged in a single well-defined pit.

In all of these genera there is a process known as the spur, which arises from the dorsal shell margin just posterior to the cardinal, and extends out over the chondophore. In the mactroid species this is often fused to the partitioning ridge above mentioned in such a way as to separate the ligament distinctly from the resilifer. In other cases the spur coalesces with the dorsal margin of the shell, forming a roof over the upper end of the pit for the resilium.

Three areas adjacent to the cardinals have been named by Dall¹² the anterior, the posterior and the ventral sinuses. The anterior sinus is situated between the anterior arm of the cardinal and the dorsal margin of the shell. The posterior one bears a similar relation to the posterior arm. The area between the cardinal arms and the ventral margin of the hinge plate is known as the ventral sinus.

VARIATIONS OF THE ELEMENTS OF THE MACTRINE SHELL

The various elements of the shell that might have a taxonomic value would include: the general shape, the position of the beaks, the type of the pallial line with its sinus, the muscle scars, and the dental armature. The utility of these characters will depend upon their specific constancy. It is therefore important for the purposes of this paper to discuss each of these details of the mactrine shell.

The members of this subfamily are found to vary specifically from an equivalve and nearly equilateral form such as *Mactra californica* to the inequilateral species *Spisula hemphillii*, and from the slightly convex form of the latter to that of the very ventricose species *Mactra exoleta*. The outlines of the mactrine shell vary from a trigonal to an elongate type, which may be illustrated respectively by the species *Spisula merriami* and *S. falcata*. Of even more immediate interest are those variations that occur within a single species.

If a number of mactrine forms are studied, it is found that there is a marked degree of variation of the general shape within the

¹² *Op. cit.*, p. 864.

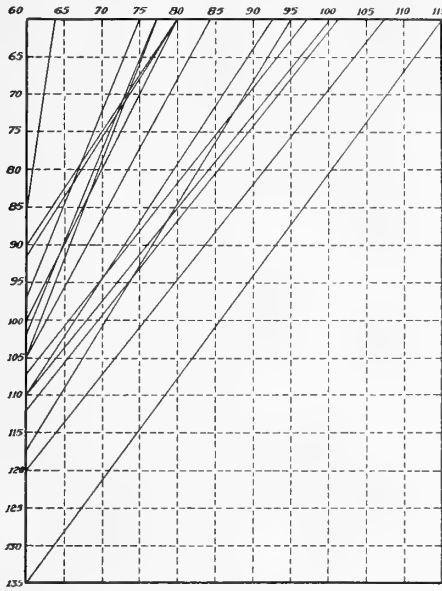
limits of certain species; while others appear quite constant when the same character is considered.

This form-variation is rendered comprehensible by graphic methods. In figure 1 the abscissas represent the height and the ordinates the length of the shell. A line connecting the two points which correspond to these dimensions represents the ratio of the length to that of the height of the shell. These measurements, based upon a number of specimens, when plotted in this manner show a series of lines in which deviation from parallelism indicates the inconstancy of these ratios for the specimens under consideration.

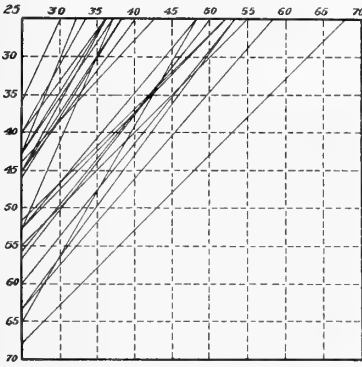
The graphs show that *Spisula selbyensis* (fig. 1f) is the least constant, and that *Mactra californica* (fig. 1c) is the most constant of the mactrine species represented. The graphs of *S. ashburnerii* (figs. 1d, 1e) and *S. merriami*, show but little variation, suggesting that they are readily separable upon the basis of their general shape. *Mulinia densata* and *S. selbyensis* are among the more variable forms shown.

The species represented that are shown to be the more variable, are difficult of determination. *Mulinia densata* and *Spisula selbyensis* are often confused with such forms as *M. pabloensis* and *S. albaria*, or even with other less closely related species. The variations in the general shape of *S. catilliformis*, especially in the case of juvenile specimens, include forms closely resembling *Schizothaerus nuttallii*.

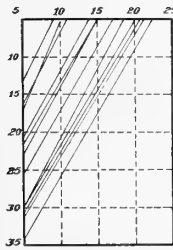
Figure 1a shows the variations of *Spisula catilliformis* through several geologic periods. This graph is based upon specimens from different beds ranging in age from Lower San Pablo to and including the Recent. Such studies suggest that as time advanced this species became more constant as regards general shape. Specimens from the Lower San Pablo show shape-variations greater than have been observed in the living species. This, together with evidence shown by the graphs of *Mulinia densata* (fig. 1b) and *Spisula selbyensis* (fig. 1f), and still further augmented by a consideration of a number of species not here plotted, suggests a remarkable inherent variability of the Miocene species in contrast to those of earlier or later periods. No adequate explanation of this has been found, unless it be that this indicates a period of specific unstability due perhaps to adaptations to the shifting local environments of the Miocene and to the aggressiveness or capacity for variation often characterizing the earlier stages in the life-history of a genus or other group.



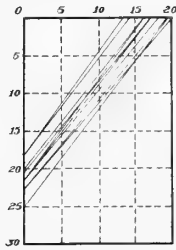
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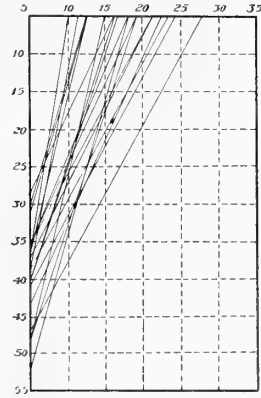
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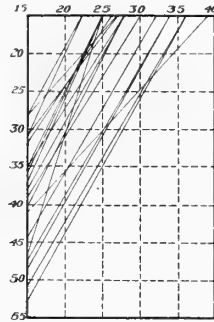
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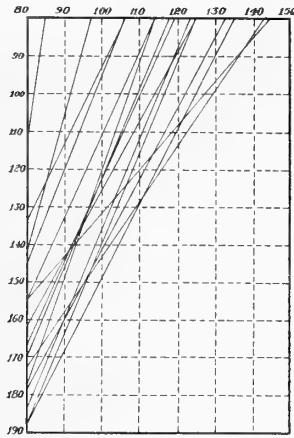
d



e



f



g

Figs. 1a to 1g. Graphs showing ratios of lengths to heights: 1a, *Spisula catilliformis*; 1b, *Mulinia densata*; 1c, *Mactra californica*; 1d, *Spisula ashburnerii*; 1e, *Schizothaerus nuttallii*; 1f, *Spisula selbyensis*; 1g, variations in the position of the beaks in *S. selbyensis*.

The charts give no definite clue to the relative variations within genera, for each genus includes species of a great range of variability. This inconstancy of form-variation is not confined to the subfamily, since it is also evident in the lutrarine species *Schizothaerus nuttallii* (fig. 1e).

If each of the specimens within the groups charted above had not possessed characters that were constant for the given species, it might be thought that measurements had been taken upon specimens representing more than a single species. Not only did each suite of shells have constant characters, but in every instance there were gradational forms connecting the extremes within the group.

If it be granted that the conclusions, based upon the measurements and other less precise methods given above, are legitimate, it is manifest that for some species, at least, the general outline of the shell is not a character of any considerable taxonomic value. Although it serves admirably in some instances, it fails in many others and therefore it cannot be employed as a specific criterion that is equally applicable to all of the members of this subfamily.

The prominence of the beak and its position with reference to the anterior extremity, have often been used as important specific characters in the definitions of mactrine species. The relative amount of shifting of the umbones within the limits of a single species is shown in figure 1g. In this graph the abscissas represent the distance from the umbones to the anterior extremity, measured along a line parallel to that of the greatest anterioposterior diameter, and the ordinates represent the greatest length of the shell. The same suite of specimens of *Spisula selbyensis* used in the previous instance was made the basis for these measurements. The scarcity of parallel lines in this chart indicates the marked amount of variation in the position of the beaks. Upon comparison with the graph of length-height ratios of the same species (fig. 1f) it is found that these ratios are more nearly constant than are those based upon the relative position of the umbones. Similar conditions occur in *Mulinia densata*, *M. pabloensis*, *Spisula albaria* and *S. abscissa*.

The shape and the prominence of the umbones are noteworthy variants within the limits of certain species such as *Mulinia densata*. In the more ventricose *Pseudocardium* forms the beaks are very prominent, in marked contrast to the small ones of the typical form.

Gradational shapes connect the extremes of such a series. The tumid specimens of this species also show considerable variation in the juxtaposition of the umbones, ranging from a condition in which they are closely approximate to that in which they are widely separated in the two valves.

The pallial sinus is a conspicuous shell character and has often been considered as having a certain classificatory value. As a means of distinguishing *Spisula catilliformis* from the lutrarine species *Schizothaerus nuttallii* the pallial sinus may be successfully employed; and it is, no doubt, likewise applicable in other instances, especially if the comparisons are not made between closely related species. Nevertheless, Dall's¹³ conclusions regarding the pallial sinus for the Pelecypoda in general will also apply to the subdivision of this class to which the mactrine shell belongs. Since the muscle scars are also of doubtful taxonomic value they need not be discussed here.

Several different types of hinge plates are observable among the Pacific Coast Mactrinae. A broad, flat one, which is more or less closely associated with an elongate form of shell, is seen in *Spisula catilliformis* (see Plate 17), *S. voyi* or *S. falcata*, while an extremely narrow hinge plate is seen in *Mactra exoleta* or *S. selbyensis*. The shape of the chondophore is modified to a certain extent by the dynamic forces which determine the general form of the shell. The elongate specimens of *Mulinia densata* or *Schizothaerus nuttallii* possess relatively shallower and broader resilifers than do the shorter individuals of the same species. This suggests a possible difficulty in the way of using the hinge for the basis of classification. A similar response to the changing shape of a species might be conceived as applying to the entire dentition and thereby depreciating the value of the taxonomic system advocated in this paper. In so far as there is a variation in shape involving the dorsal portion of the shell, just so far must there, of necessity, be an accommodation of the dental armature to these changing conditions. In the case of an anterioposterior compression of a shell, as may be seen in the ventricose forms of *Mulinia densata*, a corresponding crowding of the dental units is inevitable; but regardless of this concentration of the elements there still remain certain fundamental differences, for this crowding involves all of the elements of the hinge in such a way that each tooth

¹³ Dall, W. H., Am. Jour. Sci. (3), vol. 38, p. 446, 1889.

still retains its relative position with reference to that of the others.

Dall¹⁴ has shown that the maetrine cardinal tooth revolves, as it were, upon an axis in such a manner that the cardinal arms occupy different positions upon the hinge plate in the different species. This apparent rotation is seen most clearly in the right valve. *Spisula catilliformis* and *S. planulata* serve as extreme examples of this condition. Although this shifting of the position of the cardinal arms is noticeable when different groups are studied, it is negligible when species are considered among themselves. In certain forms there is a marked tendency for the arms of the left cardinal to thicken in such a way as to form a massive triangular block-tooth instead of the typical maetrine cardinal composed of two distinct arms. This condition appears to be common in the heavy, thick-shelled forms like *Mulinia densata*. A similar tendency is seen in *Mulinia alta*, where a thickening of the cardinal arms occurs, although the hinge teeth are much more delicate than in the form just mentioned. The shorter specimens of *Schizothaerus nuttallii* appear to have the same type of cardinals. This may be attributed in part to senility, but not entirely so, for the younger specimens show the same tendencies to a lesser degree. The relative height of the cardinal is variable. It is perhaps less noticeably variable in the maetroid species than in the spisuloid ones.

In discussing the laterals Dall¹⁵ writes: "the paired laminae are more variable than the single ones". There is, then, a recognized variation of the laterals as well as of the cardinals. This variation may be expressed in terms of length, height and thickness of the teeth. The lamella on the arm of the left cardinal is so fragile that it is seldom seen on fossil specimens, and only occasionally in Recent material. It is quite variable in most of the maetrine species, judging from the few specimens in which it has been seen and from its known inconstancy in the indigenous lutrarine species.

The question now arises regarding the status of a proposed classification based primarily upon a hinge which is as inconstant as has been indicated above. Dall¹⁶ says: "The distribution of the parts of the hinge in a single species is remarkably uniform, but if groups of species are considered, the types seem to gradually approach and almost merge one in another." After making this the

¹⁴ Dall, W. H., Trans. Wagner Inst. Sci., vol. 3, pt. 4, p. 869, 1898.

¹⁵ *Op. cit.*, p. 868.

¹⁶ *Op. cit.*, p. 867.

basis of considerable study, the writer would agree with Dall regarding the constancy of these relationships and he would further state that this distribution of the elements of the hinge offers the most reliable known basis for the classification of this family.

The greater constancy of the laterals as compared with the laminae of the right valve, and the greater constancy of the form of the left cardinal give the greater taxonomic value to the left valve.

A study of the cardinal tooth of the left valve shows that in different species it occupies various positions on the hinge plate; from that at the dorsal margin of the plate, as in *Mactra nasuta* or *Spisula catilliformis*, through a condition in which it is about centrally located on the hinge plate, as in *Mulinia densata*, to that seen in *S. albaria* or *Mactra exoleta*, in which the cardinal arises from the ventral margin of the plate. The laterals in some cases arise confluent with the edges of the hinge plate, as in *S. selbyensis* or *Mulinia densata*, or they may be set some distance from the margin, as in *Mactra nasuta* or *S. voyi*.

It has been shown above that the general shape of the shell, the position of the umbones, and the character of the pallial sinus are more inconstant than are the hinge characters, and therefore they are only of secondary importance in defining a mactrine shell.

In the systematic portion of this paper the species have been grouped into subgenera and sections wherever it has been possible. These lesser divisions are of use inasmuch as they show the relationships that exist within a genus. The subgeneric groups, as defined by Dall, are based upon the differences of the dental armature, due consideration having been given to any other character of the shell that appeared to have a taxonomic value.

THE HISTORY OF THE MACTRINAE

The geologic and geographic distribution of the West Coast *Mactrinae* have a phylogenetic as well as an economic interest. The oldest known species, *Spisula ashburnerii* (Gabb), has been reported from the Horsetown Beds; it has a long range, being found abundantly in the upper portion of the Chico, where it is associated with *S. gabbiana* (F. M. Anderson) and *S. chicoensis*, new name. The

first two of these are known to occur at upper Cretaceous localities from British Columbia to the Santa Ana Mountains, California.

Two maetrine species are now known from the Martinez Eocene of this region. One, *Maetra* (?) *tenuissima* Gabb, has been recognized by Dickerson,¹⁷ in material obtained from the Martinez group of Lower Lake, Lake County, California. The other, *Spisula* (?) *weaveri* Packard, appears to be characteristic of the lower Eocene of Mount Diablo and of the Santa Ana Mountains, California. The genera of these forms have not been definitely determined, due to inability to observe the hinges, and therefore they can have no place in a phylogenetic discussion.

Four species are known from the upper Eocene. Two, *Spisula merriami*, n. sp., and *S. tejonensis*, n. sp., have a wide geographic range, occurring abundantly at a number of Tejon localities throughout the state, and *S. tejonensis*, n. sp., has been questionably recognized by the writer from strata of approximately the same age at Vader, Washington. The new species *Spisula acutirostrata* occurs at the type locality of the Tejon group in California. The species *S. callistaeformis* Dall, comes from the Stepovak series of Alaska.

Spisula albaria ramonensis, n. var., and possibly *S. occidentalis* (Gabb) are restricted to the Agasoma gravidum zone, which according to B. L. Clark is of Oligocene age.

Eleven species and one variety of well-known Maetrinae occur within the Miocene strata of this region. This number is increased by the following imperfectly known forms: *Spisula lenticularis* (Gabb), *S. montereyana* (Arnold) and *Mulinia landesi* (Weaver). Three and possibly four maetrine species are known in the Monterey series, as now recognized, exposed in the vicinity of Mount Diablo, California. *S. catilliformis* Conrad has been reported from the Temblor of the Kern River district, Kern County, California, associated with a fauna that is thought by B. L. Clark to be equivalent to the Arca montereyana zone of the Mount Diablo section. *S. selbyensis*, n. sp., and a mulinoid form not distinctly separable from *Mulinia densata* Conrad also occur in this zone. Its variety, *M. densata* var. *minor* occurs in the Turritella ocoyana zone of the Coalinga district. The lower San Pablo maetrine fauna consists of *Spisula abscissa* (Gabb), *S. albaria* (Conrad), *S. catilliformis*

¹⁷ Dickerson, R. E., Fauna of the Martinez Eocene of California, Univ. Calif. Publ. Bull. Dept. Geol., vol. 8, p. 96, 1914.

[illegible]

GEOLOGIC AND GEOGRAPHIC RANGE OF THE PACIFIC COAST MACTRINAE

	Recent										Pleis- tocene	Pliocene		Miocene				Oligocene	Eocene		Cretaceous				
	Alaska	Vancouver Island	Straits of Juan de Fuca	San Francisco	Monterey	Santa Barbara	San Pedro	San Diego	Gulf of California	Panama	San Pedro fauna	Merced fauna	Parisma-Elcheco fauna	Jacalitos fauna	Upper San Pablo fauna	Lower San Pablo fauna	Scutella breweriana zone	Turritella ocoyana zone	Turritella incana zone	Azozoma gravidum zone	San Lorenzo fauna	Tujon fauna	Martinez fauna	Chico fauna	Horseshoe fauna
<i>Macra californica</i> Conrad	x	...	x	x	x	x	x	x	x	...	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>Macra dolabriformis</i> (Conrad)	x	...	x	x	...	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>Macra exoleta</i> Gray	x	...	x	x	...	...	...	...	...	...	...	...	...	...	...	...	?	...
<i>Macra (?) gibbsana</i> Meek
<i>Macra (?) montereyana</i> Arnold	x	...	...	x	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>Macra nasuta</i> Gould	x	...	...	x	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>Macra (?) stantoni</i> Arnold	x	...
<i>Macra (?) tenuissima</i> Gabb	x	?	...
<i>Macra trampasensis</i> , n. sp.
<i>Melina alta</i> (Weaver)	?
<i>Melina densata</i> Conrad	x	x	?	...	x	...	...	...	...	...	...	...	...
<i>Melina densata</i> var. <i>minor</i> Arnold	x	...	...	...	...	...	...	...	...
<i>Melina landesi</i> (Weaver)	?	x	...	...	...	...	...	...	...
<i>Melina pabloensis</i> , n. sp.	?	?	?
<i>Melina undilifera</i> (Weaver)	?
<i>Spisula abscissa</i> (Gabb)	x	...	...	...	...	...	...	...	...	...
<i>Spisula acutirostrata</i> , n. sp.	x	...	...	...
<i>Spisula albaria</i> (Conrad)	x	x	x	x	x	...	...	...	...	...	...	...	...	...
<i>Spisula albaria</i> var. <i>ramonensis</i> , n. var.	x	...	...	...	...	...
<i>Spisula ashburneri</i> (Gabb)	x	?
<i>Spisula brevirostrata</i> , n. sp.	x	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>Spisula callistaeformis</i> Dall	?
<i>Spisula catilliformis</i> Conrad	x	x	...	x	x	...	...	x	x	x	x	x	x	x	x	x	...	...	...	...	...	...	...
<i>Spisula chicoensis</i> , n. name	x	...
<i>Spisula coalingensis</i> (Arnold)	x	...	...	...	...	...	...	...	...	...	...	...	...
<i>Spisula falcata</i> (Gould)	x	x	...	...	...	x	...	x	...	...	x	...	x	...	?	...	...	...	...	...	...	...	...	...	...
<i>Spisula gabbiana</i> (Anderson)	x	...
<i>Spisula hemphilli</i> (Dall)	x	x	...	...	x	...	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>Spisula lenticularis</i> (Gabb)	?
<i>Spisula mercedensis</i> , n. sp.	x	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>Spisula merriami</i> , n. sp.	x	...	...	...
<i>Spisula occidentalis</i> (Gabb)	?	...	x	...	...	...	...	...
<i>Spisula planulata</i> (Conrad)	x	x	...	x	...	...	...	...	...	...	...	...	...	...	...	...	...	x	...	...	...
<i>Spisula tejonensis</i> , n. sp.
<i>Spisula selbyensis</i> , n. sp.
<i>Spisula sisquocensis</i> Arnold
<i>Spisula voyi</i> (Gabb)	x	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>Spisula (?) weaveri</i> Packard	x	x	x	...	...	...	...	...	...	...	...	x	...	...	...	...	...	...	...	...	...	...	?	x	...

Conrad, *Mulinia densata* Conrad and *M. pabloensis*, n. sp. Only the first of these is restricted to this portion of the series, its highest known range being the base of the *Astrodapsis whitneyi* zone of the middle San Pablo. To this zone belongs the earliest undoubted mactroid species, *M. trampasensis*, n. sp. To the upper San Pablo belong the following forms: *Spisula albaria* (Conrad), *S. catilliformis* Conrad, *Mulinia densata* (Conrad) and *M. pabloensis*, n. sp. The last-mentioned is restricted in its upward range to the top of the San Pablo.

The exact stratigraphic position of the following Miocene species has not been definitely determined with reference to the standard California section: *Mulinia landesi* (Weaver), *M. alta* (Weaver) and *M. undilifera* (Weaver).

The following species range through the Jacalitos into the Etchegoin formation: *Spisula albaria* (Conrad), *S. catilliformis* Conrad and *Mulinia densata* Conrad. *S. coalingensis* (Arnold) is known only from the Etchegoin. Two other species, *S. voyi* (Gabb) and *S. brevirostrata*, n. sp., occur at a questionably equivalent stratigraphic position in the Wildeat series of Humboldt County, California.

The Merced fauna of the San Francisco Peninsula has yielded the following mactrine species: *Spisula albaria* (Conrad), *S. catilliformis* Conrad, *S. mercedensis*, n. sp., and *S. falcata* (Gould). Two of these, *S. albaria* (Conrad) and *S. mercedensis*, n. sp., became extinct at the close of the Pliocene.

The San Pedro or Pleistocene fauna is characterized by the appearance of two mactroid species of widely different types. The known Pleistocene species include: *Mactra californica* Conrad, *M. exoleta* Gray, *Spisula catilliformis* Conrad, *S. falcata* (Gould) and *S. hemphillii* (Dall). *S. voyi* (Gabb) may be mentioned here, since it is known to occur both in the Pliocene and Recent faunas. Its absence from the San Pedro fauna may be due to the fact that it is a northern species, being at present limited in its southward range by the Straits of Juan de Fuca.

Three species, *Mactra dolabriformis* (Conrad), *M. nasuta* Gould, and *Spisula planulata* (Conrad) are known definitely only in the Recent fauna. To these should be added the above-mentioned Pleistocene forms, giving a list of four mactroid and five spisuloid species known to the waters of the Pacific Coast north of Mexico.

The geographic range of the Recent species and the vertical range of the fossil species are shown on the accompanying chart, in which the periods are divided into stages according to the faunas.

PHYLOGENY OF THE PACIFIC COAST MACTRINAE

The genus *Spisula* is the first genus of the Mactrinae to appear within this Pacific Coast region. It is doubtfully represented in the Horsetown Beds by *S. ashburnerii* (Gabb), the typical species of the subgenus *Cymbophora*. Higher in the Cretaceous, this form is associated with *S. gabbiana* (F. M. Anderson) and *S. chicoensis*, new name. These three are characterized by having a spoon-shaped chondophore with raised margins and a type of right cardinal in which the anterior arm is lacking. This typical Cretaceous group is replaced in the Eocene by the subgenus *Hemimactra* in which the chondophore is submerged below the level of the hinge plate and in which the right cardinal bears two well-developed arms. By the middle of the Miocene this subgenus was the dominant one of the family, including the great majority of the Tertiary species, many of which had a wide geographic range. The genus *Spisula* reached its maximum during the late Miocene, declining in importance until at present it is represented by but one more species in this Coast region than is the younger genus *Mactra*.

The first undoubted mactroid species appears in the San Pablo. It is not until the Pleistocene that this genus holds an important place in the fauna of the region, being represented at that time by two groups of species. These two subgenera, *Mactrotoma* and *Mactrella*, are quite widely separated groups. The latter appeared earlier on this Coast, being represented by the species *Mactra trampasensis*, n. sp. To the former belong the greater number of Recent species. The genus *Mactra* appears at present to be at its maximum of development.

The phylogenetic history of the genus *Mulinia* on the West Coast of the United States is characterized by its sudden appearance, rapid dispersal and abrupt disappearance. It first appears in the early Miocene. By the time the San Pablo stage was reached, this genus had become differentiated into several types, that were distributed over the coast from Washington to southern California.

By the close of the Neocene these forms became extinct. The genus is now known on the Pacific Coast only from the Panama province.

The Miocene was the period of the greatest generic and specific differentiation of the family. Previous to that time the species were few in number and relatively constant in shape. During that period a considerable number of new forms appeared, most of which were exceedingly variable, giving rise to a number of species, many of which became extinct during the Pliocene. A few of the less variable forms persisted through to the Recent. Specific differentiation increased until the present fauna is characterized by clearly defined species which are in general not closely related to one another.

CONCLUSIONS

Of all the principal parts of the shell, the mactrine hinge is the least variable within the limits of a single species. It varies somewhat as regards relative height or thickness of the teeth, but the relative positions of the dental elements with reference to one another are remarkably constant for a given species, and therefore serve as important bases for specific classification.

The known mactrine forms include five mactroid species, one of which is here described for the first time. The genus *Spisula* is represented by twenty-three species, six of which are new. The hinges of eighteen of these have been studied. Three species and two varieties of *Mulinia* are recognized, one of the species being considered as new.

SYSTEMATIC DESCRIPTIONS

Superfamily MACTRACEA Gray, 1837

Resilium situated on a chondophore; bifid cardinal in the left valve fits below the two cardinal arms of the right valve.¹⁸

Family MACTRIDAE Gray, 1837

Shell trigonal, equivalve; posterior gape more or less evident; umbones prosogyrate; hinge plate well-developed, subtrigonal in

¹⁸ This and the following definitions of the family, genera, subgenera and sections are based almost exclusively upon Dall's paper published in the Proceedings of the Malacological Society of London, vol. 1, pp. 203-213, 1895.

shape; ligament internal or external; chondophore excavated; a bifid \wedge -shaped cardinal in the left valve fitting between the two arms of the cardinal of the right valve; posterior and anterior laminae well-developed; accessory lamellae often present; pallial line often sinuated; siphons united; epidermis present.

Subfamily MACTRINAE Dall, 1894

Shell subequilateral; gape slight in most forms, never pronounced; siphons may be retracted within the shell; epidermis covering the siphons not markedly developed.

Genus MACTRA Linnaeus, 1758

Type *Mactra stultora* Linnaeus

Plate 12, figures 1a and 1b

Shell ovate-trigonal, subequilateral; chondophore roofed at the apex; spur distinct; ligament separated from the resilium by a shelly ridge.

Subgenus *Mactrotoma* Dall, 1894

Type *Mactra fragilis* Gmelin

Shell with a depressed band on the dorsal area; sculptured; umbones adjacent; gape pronounced; resilifer large, shallow, apically roofed; cardinals prominent, but thin; posterior arm of the cardinals overhangs the chondophore; accessories on the posterior arms; anterior laminae arising from the dorsal sinus; pallial line distant; epidermis thin and silky.

Section *Mactrotoma* Dall, 1894

Mactra nasuta Gould is the first species mentioned by Dall.

Accessories coalescent with laterals and cardinals.

MACTRA NASUTA Gould

Plate 12, figures 2a, 2b and 2c

Mactra nasuta Gould, Boston Soc. Nat. Hist., vol. 4, p. 88, 1851; Dall, Nautilus, vol. 8, p. 39, 1894; Keep, West Coast Shells, p. 105, 1911.

Mactra californica Deshayes, Proc. Zool. Soc. London, 1854, p. 68.

Mactra fragilis Carpenter, Brit. Assn. Rept. 1856, p. 304.

Mactra deshayesii Conrad, Am. Jour. Conch., vol. 3, appendix, p. 46, 1868.

The dimensions of the specimen figured are: length 33.5 mm., height 23 mm., convexity 6 mm.

The lack of the sulcate beaks, the more pronounced gape, the more ventricose form, besides several details of the hinge will serve to separate this species from *Mactra californica*, with which it is often associated.

This Recent species was described from a specimen obtained from San Pedro, California. The species is not certainly known to occur in beds older than the Recent.

Occurrence.—Recent: San Pedro, California, to West Columbia. (Dall).

Section *Simomactra* Dall, 1894

Type *Mactra dolabriformis* (Conrad)

Laminae lacking accessories.

MACTRA DOLABRIFORMIS (Conrad)

Plate 12, figures 3a, 3b and 3c

*Spissula*¹⁹ *dolabriformis* Conrad, Am. Jour. Conch., vol. 3, p. 193, 1867.

Spisula dolabriformis (Conrad), *op. cit.*, appendix, p. 44.

Mactra dolabriformis Conrad, Dall, Nautilus, vol. 7, p. 138, pl. 5, fig. 1, 1894; Keep, West Coast Shells, p. 105, 1911.

This species was described from a Recent specimen obtained from Panama. Neither figure nor dimensions of this specimen were given. Dall in a redescription of this form gives the following dimensions: length 90 mm., height 63 mm., convexity 13 mm.

This species might be confused with *Spisula falcata*, from which it differs in its mactroid type of hinge, more elongate shape and more pronounced umbonal ridge.

Occurrence.—Recent: San Diego, California to Panama (Dall).

Section *Micromactra* Dall, 1894

Type *Mactra californica* Conrad

Shell small with sulcate beaks.

¹⁹ This spelling of the generic name is evidently a typographical error since it is spelled correctly by the same writer in the appendix of the same volume.

MACTRA CALIFORNICA Conrad

Plate 16, figures 4a, 4b and 4c

Mactra californica Conrad, Jour. Acad. Sci., Philadelphia, vol. 7, p. 240, pl. 18, fig. 12, 1837; Dall, Nautilus, vol. 8, p. 40, 1894; Dall, Trans. Wagner Inst. Sci., vol. 3, pt. 4, p. 876, 1898; Arnold, Mem. Cal. Acad. Sci., vol. 3, p. 174, pl. 19, fig. 2, 1903.

Mactra augusta Deshayes, Proc. Zool. Soc., London, 1854, p. 67.

This species was described by Conrad as follows:

Shell triangular, compressed, equilateral; posterior margin rectilinear; posterior side with a carinated, rectilinear, submarginal line; beaks prominent, sulcated; epidermis brown, with concentric wrinkles; teeth lamellar, large, very prominent.

The hinge plate of this species is broad and flat; chondophore shallow, apically roofed, triangular in shape, overhung but slightly by the arm of the cardinal; left cardinal prominent, high, thin, without accessories; anterior arm longer than the posterior, neither reaching to the ventral margin of the hinge plate; right cardinal also high, thin, arms fused along the dorsal side of the tooth; anterior arm makes a relatively wide angle with the anterior dorsal margin of the shell; laminae smooth; anterior lateral bifid, the dorsal portion being usually the thinner and possessing the character of a lamella; this tooth is short and high, originating as a low ridge dorsal to the middle of the anterior cardinal arm and extending parallel to the ventral margin of the hinge plate; anterior ventral lamina very small, inserted upon the dorsal margin of the shell; posterior laminae short, the small dorsal one arising from the shell margin. Pallial line distant, with a deep and rounded sinus which reaches nearly to the middle of the shell and joins confluent for a short distance with the pallial line. The measurements of the type as inferred from the original cut are: length 36 mm., height 23 mm.

This species has been confused with *Spisula catilliformis*, the latter having been listed in much of the literature under the name of the former. Specimens of these two species are easily distinguishable. *M. californica* resembles *S. falcata* in outline, but it is separable from that species upon the basis of its sulcate beaks, and prominent cardinal with its widely diverging arms. It differs from *M. nasuta* in being more ventricose, and in possessing longer laterals.

This species was described from a Recent specimen obtained from near Santa Barbara, California.

Occurrence.—Recent: Straits of Juan de Fuca to Central America (Dall). Pleistocene: San Diego and San Pedro (Arnold).

Subgenus *Mactrella* Gray, 1853

Type *Mactra alata* Spengler

Shell thin, ventricose, trigonal, with a ridge marking off the posterior dorsal area; umbones prominent; dental armature concentrated; normal, narrow ligament; anterior laminae very short.

MACTRA EXOLETA Gray

Plate 12, figures 4*a* and 4*b*; plate 13, figure 2

Mactra exoleta Gray, Mag. Nat. Hist. 1837, p. 372; Carpenter, Proc. Zool. Soc., London, pt. 24, p. 200, 1856; Brit. Assn. Repts. 1856, p. 246; Dall, Nautilus, vol. 8, p. 40, 1894; Arnold, Mem. Cal. Acad. Sci., vol. 3, p. 175, pl. 19, fig. 4, 1903.

Lutraria ventricosa Gould, Boston Jour. Nat. Sci., vol. 4, p. 88, 1851.

Mulinia ventricosa A. Adams, Annals Nat. Hist. N. Y., vol. 5, p. 517, 1852.

Mactrella exoleta Carpenter, Brit. Assn. Repts. 1863, p. 543.

Shell subtrigonal, very ventricose; beaks prominent, slightly anterior to the middle of the shell; anterior dorsal edge straight; anterior end very broad and regularly rounded; posterior dorsal edge convex, sloping abruptly to the truncated posterior extremity; base broadly arcuate; a prominent umbonal ridge extends from the beaks to the posterior extremity; the area posterior to this line is nearly flat. Surface smooth or slightly roughened by lines of growth.

Hinge plate rather narrow; chondophore deep, apically roofed, divided into two areas by a well-developed shelly ridge characteristic of the genus *Mactra*, overhung by an accessory lamella, which arises from the posterior arm of the left cardinal; left cardinal prominent; posterior arm slightly shorter than the anterior; cardinal reaching ventrally from the dorsal margin of the shell to the ventral margin of the hinge plate; right cardinal with a very heavy anterior arm, which is appressed to the shell margin and extends about three-fourths of the distance to the ventral margin of the hinge plate; posterior arm thin and slightly overhanging the resilifer; arms not

coalescent dorsally; laminae smooth, the groove between the anterior ones being very deep; anterior lateral very short, distant from the cardinal and arising from the ventral edge of the hinge plate; posterior one also short and distant from the umbones; ventral lamina well developed, dorsal ones very small. Pallial sinus very shallow and angular. The dimensions of the specimen figured in this paper are: length 44 mm., height 34 mm., convexity 13 mm.

This ventricose and angulated species is easily separable from the other known Pacific Coast Mactrinae upon the basis of the general shape, which is quite constant in all of the specimens examined.

Mactra exoleta has been reported from the Pliocene of Washington but the specimen figured scarcely seems determinable.²⁰

This species was described from a Recent specimen.

Occurrence.—Recent: San Diego, California, to Guayquil, Ecuador (Dall). Pleistocene: San Diego, San Pedro (Arnold); Newport, California.

MACTRA TRAMPASENSIS, n. sp.

Plate 13, figure 3; plate 16, figures 1 and 2

Shell medium-sized, very ventricose, trigonal to subovate, nearly as high as long, and nearly equilateral; sculptured by faint distant concentric lines; beaks prominent, incurved, distant; posterior dorsal slope somewhat concave, with an ill-defined escutcheon; anterior dorsal slope concave, marked by a well-defined impressed lunule; anterior and posterior extremities about equally rounded, ventral margin broadly rounded. Hinge plate narrow; chondophore deep, nearly circular in outline, slightly overhung by the cardinal, probably roofed by a spur; left cardinal arms heavy; anterior arm slightly longer than the posterior, reaching from the dorsal margin of the shell to the ventral margin of the hinge plate; right cardinal partially destroyed; anterior arm strong, low, apparently confluent with the ventral lamina; laminae smooth; anterior lateral confluent with the anterior arm of the cardinal; posterior lamina low, long. Pallial line is unknown. The dimensions of the type specimen are: length 48 mm., height 38 mm., convexity 14 mm.

The distinctive shape readily separates this species from other Pacific Coast Mactrinae. The few specimens that are known show but little variation in general shape.

²⁰ Reagan, A. B., Kan. Acad. Sci., vol. 22, p. 212, pl. 4, figs. 42a, 42b, 1909.

The type was obtained from University of California Locality 1237: Top of knob about one-quarter of a mile south-east of Burton's and about one and one-half miles north of Los Trampas Creek, Concord Sheet, Contra Costa County, California.

Occurrence.—Miocene: San Pablo group, Contra Costa County, California.

Genus *SPISULA* Gray, 1837

Type *Mactra solida* (Linnaeus) Gray

Shell generally small, nearly equilateral; beaks adjacent; dorsal area not set off by a definite ridge or keel; gape obsolete; ligament and resilium not separated by a shelly partition; ligament sagitate, partially external; chondophore shallow, often roofed over by a spur; cardinal small and often overhanging the chondophore; anterior arm of the right cardinal is close to the dorsal margin of the shell; laminae heavy, often grooved; pallial sinus small, evenly rounded; epidermis thin.

Subgenus *Hemimactra* Swainson, 1840

Type *Mactra solidissima* Dillwyn

Plate 6, figures 1a and 1b

Shell large, trigonal; dorsal area not distinctly grooved; teeth somewhat concentrated; cardinals small, compressed; anterior arm of the cardinal generally confluent with the ventral lamina; the laminae are often distinctly grooved.

Section *Mactromeris* Conrad, 1868

Type *Mactra polynyma* Stimpson

Laminae smooth, ventral lamina not confluent with the anterior arm of the cardinal.

SPISULA VOYI (Gabb)

Plate 13, figure 4; plate 14 and plate 15

Callista voyi Gabb, Pal. Cal., vol. 2, p. 24, pl. 5, fig. 41, 1869.

Mactra ovalis Gould, Middendorf, Reise in den Aeussersten Norden und Osten Sibiens, bd. 3, p. 363, 1843-1844.

Spisula polynyma (Stimpson), Dall, Nautilus, vol. 7, p. 138, 1894.

Spisula polynyma (Stimpson) var. *alaskana* Dall, Nautilus, vol. 8, p. 40, 1894.

Spisula alaskensis Dall, U. S. Geol. Surv. Prof. Paper, no. 59, p. 131, 1909.

Mactra (*Spisula*) *alaskana* Dall, Baker, Nautilus, vol. 24, p. 46, 1910.

This species was described by Gabb as follows:

Shell broad, inequilateral; beaks in advance of the middle; cardinal margin nearly straight and sloping; anterior end very much produced, rounded and narrow; posterior end obliquely truncated; base broadly and regularly rounded. Surface marked by numerous irregular and rather strong lines of growth.

The hinge plate of this species is wide, the chondophore oblique, shallow, very slightly overhung by the posterior arm of the cardinal; left cardinal heavy, high, situated on the dorsal portion of the hinge plate; arms heavy, of equal length, free from accessories, ventral sinus excavated; right cardinal low, anterior arm thick, appressed to the shell margin; posterior arm very thin; anterior lateral low, acutely pointed, its dorsal base extending back of, and parallel to the anterior arm of the cardinal; posterior lateral low, long, reaching as an indistinct ridge nearly to the umbones; posterior laminae low and long; anterior laminae very short; dorsal one arises from the margin of the shell. Pallial sinus of the Recent specimens deep, rounded and oblique to the pallial line. This is not shown in the plesiotype. The dimensions of the plesiotype are: length 85 mm., height 60 mm., convexity 18 mm.

This species was described from a fossil specimen obtained from below Bear River, Humboldt County, California. Several specimens from Eel River, Humboldt County, were labeled *Callista voyi* by the State Geological Survey. One of these corresponds in outline and size to Gabb's conventional figure. The hinge of this specimen has been exposed. Its mactrine character was first recognized by Dr. Merriam.²¹ The complete dentition is now known from the specimens obtained from the above-mentioned region. A study of these together with the type shows that they are identical with *Spisula alaskana* of the Recent fauna.

The hinge of this species might be confused with that of *S. catilliformis*. It differs from that species in that the anterior lateral is never fused to the anterior arm of the cardinal and that the posterior laminae are much more elongate.

The fossil forms are slightly more ventricose than are the few available Recent specimens. The general shape of both the fossil and Recent specimens varies considerably as regards the relative lengths of the shells.

²¹ Merriam, J. C., A list of the type specimens in the Geological Museum of the University of California, etc., Berkeley, 1895.

Occurrence.—Recent: Icy Cape, Alaska, to Neah Bay, Washington (Dall). Pliocene: Wildeat group, Humboldt County, California.

SPISULA CATILLIFORMIS Conrad

Plates 17, 18 and 19

*Spissula*²² *catilliformis* Conrad, Am. Jour. Conch., vol. 3, p. 193, 1867.

Standella californica (Conrad), Carpenter, Brit. Assn. Rept. 1863, p. 640 (not of Conrad 1837 nor of Deshayes 1852).

Spisula catilliformis Conrad, Dall, Nautilus, vol. 7, p. 137, pl. 5, fig. 3, 1894; Arnold, Mem. Cal. Acad. Sci., vol. 3, p. 176, pl. 19, fig. 5, 1903.

Spisula catilliformis, var. *alcatrazensis* Arnold, Smithsonian Misc. Coll., vol. 50, p. 437, pl. 56, fig. 6, 1907.

Conrad described this species as follows:

Suboval, inequilateral; anterior side slightly flattened or contracted; posterior side with an oblique shallow groove or fold; lines of growth coarse and prominent; lunule very long, elliptical; ventral margin tumid posteriorly; cardinal pit oblique, large; pallial sinus extending beyond the middle of the valve.

The hinge plate of this species is wide; chondophore very large and shallow, overhung slightly by the arm of the cardinal and by a prominent spur; left cardinal heavy, large, situated on the dorsal edge of the hinge plate; arms of nearly equal length; ventral sinus wide, flat; right cardinal low, anterior arm small, appressed to the dorsal margin of the shell; posterior arm thin, overhanging the chondophore; laterals heavy, anterior lateral short, high and fused to the dorsal side of the anterior cardinal arm; posterior lateral longer and not quite so high as the anterior one; laminae very short, heavy, and close to the umbones; anterior dorsal lamina nearly in the same plane with the anterior cardinal arm. Pallial sinus deep, rounded, reaching nearly to the middle of the shell. The dimensions of the type as given by Conrad are equivalent to a length of 117.3 mm., and a height of 98.3 mm.

There is considerable variation in the outlines and especially in the convexity of the Recent specimens. If the fossil specimens are considered it is found that the variation in shape is quite marked. Those obtained from a single collecting locality from the base of the San Pablo of the Mount Diablo region vary considerably in outline, being more variable than the Recent specimens, although they possess hinges that are nearly identical with those of the Recent fauna.

The type of the variety *alcatrazensis* of Arnold was obtained from

²² See foot-note 19.

the Fernando formation from the Alcatraz asphalt mine near Sisquoc, Santa Barbara County, California. It is evident from the original description that this variety is based solely upon the general shape, for it is stated that the "hinge and the interior" are "quite similar to the typical form". It appears to differ from the typical species in its more central beaks, more depressed anterior margin and more truncated anterior extremity, but similar differences in shape are known to occur within the limits of the typical species and such characters are there considered as having little taxonomic significance.

This species has been confused with the lutrarine species *Schizothaerus nuttallii*, but it differs markedly from that species in the character of the siphonal gap and in the type of the hinge. It might be confused with *S. mercedensis*, which is a more tumid form, lacking the pronounced posterior flexure and having the anterior lateral distinctly separated from the arm of the cardinal.

The type of this species was described from a Recent specimen obtained from Panama.

Occurrence.—Recent: Straits of Juan de Fuca to San Diego, California (Dall). Pleistocene: San Pedro, San Diego (Arnold). Pliocene: Merced group. Miocene: San Pablo group; Temblor (J. P. Smith).

SPISULA MERCEDENSIS, n. sp.

Plate 13

Shell large, ventricose, inequilateral, the beaks being considerably anterior to the middle of the shell; anterior dorsal edge short, slightly concave, with a faint suggestion of a lunule; posterior dorsal edge gently convex, curving regularly to the rounded extremity; anterior end evenly rounded; base broadly arcuate; umbones small, sharply pointed; an indistinct posterior flexure extends from the umbones to the base, much as in *Spisula catilliformis* Conrad. Surface roughened by numerous irregular lines of growth. Hinge plate wide, chondophore shallow, wide, overhung but slightly by the posterior arm of the cardinal; left cardinal large, arms of equal length, high; anterior lateral short, situated dorsal to the anterior arm of the cardinal; posterior lateral high and acutely pointed. Hinge of the right valve unknown. Pallial sinus not observed. The dimensions of the type are: length 124 mm., height 93 mm., convexity 32 mm.

This species differs from *Spisula catilliformis*, with which it is often associated, in its general outline; in being more ventricose; in having an indistinct posterior flexure and in the separation of anterior lateral from the anterior arm of the cardinal.

The type of this species was obtained in the marine cliffs of the Merced group, near Mussel Rock, San Mateo County, California.

Occurrence.—Pliocene: Merced group, San Mateo County, California.

SPISULA HEMPHILLII (Dall)

Plates 21 and 22

Mactra hemphillii Dall, Nautilus, vol. 7, p. 137, pl. 5, fig. 2, 1894.

Spisula hemphillii (Dall), Nautilus, vol. 8, p. 40, 1894; Arnold, Mem. Cal. Acad. Sci., vol. 3, p. 175, pl. 19, fig. 3, 1903; Keep, West Coast Shells, p. 106, 1911.

Dall described this species as follows:

Shell large, thin, inflated, subequilateral, creamy white with a yellow, thin epidermis, which over the body of the shell in young shells is beautifully evenly concentrically striated and on the posterior dorsal area is irregularly wrinkled, with an elevated raphe of epidermis at the margin of the area; beaks rather prominent, the anterior end of the valves longer than the posterior; posterior dorsal slope excavated; lunule obscure, escutcheon marked by prominent elevated radial lines of epidermis; the dorsal margin pouting in front of the ligament, the posterior slope convex, the posterior flexure faint, but marked by a recession of the ventral border of the valves, which gap but very little and not at all in front; anterior end rounded, but smaller than the posterior; ventral border arcuate; hinge and pallial sinus much as in the last species (*S. catilliformis*), except that the sinus is smaller and less depressed.

Hinge plate rather wide, chondophore deep, apically roofed by a prominent spur, but not overhung by the cardinal arms; left cardinal high and heavy, situated on the dorsal portion of the hinge plate; arms of equal length; ventral sinus deeply excavated; right cardinal low, the cardinal arms not fused medially, anterior arm the heavier, posterior arm short and thin; anterior lateral short, high, round-topped, distinctly separate from and in nearly the same plane with the anterior cardinal arm; laminae short and heavy; anterior ventral lamina distant from, but nearly in alignment with the anterior cardinal arm; dorsal anterior lamina represented by a short, low process arising from the margin of the shell; posterior dorsal lamina shorter and thinner than the posterior ventral one.

Pallial sinus deep, oblique to the ventral margin. The dimensions of the type, which was a Recent specimen from San Diego, California, were given as: length 120 mm., height 93 mm., convexity 25 mm.

A considerable number of specimens of this species have been available for study. The species appears to be quite constant as regards the general shape as well as the dental armature.

This species might be confused with *S. catilliformis*. From that species it is separable on the basis of its shape; longer laminae; the separation of the anterior lateral from the arm of the cardinal; and the more oblique type of pallial sinus.

Occurrence.—Recent: San Pedro to San Diego, California (Dall). Pleistocene: San Pedro (Arnold); Newport, California.

SPISULA OCCIDENTALIS (Gabb)

Plate 23, figures 1, 2 and 3

? *Hemimactra occidentalis* Gabb, Pal. Cal., vol. 2, p. 54, pl. 15, figs. 13 and 13a, 1869.

This species was described by Gabb as follows:

Shell thin, subovate, inequilateral; beaks small, closely approximating, placed about two-fifths of the length from the anterior end, which is broadly excavated above, and prominently, though narrowly rounded below; posterior end convexly and obliquely sub-truncated; cardinal margin sloping and nearly straight, base broadly and regularly convex; a moderately distinct angle runs from the beaks to the posterior basal margin. Surface covered by small but moderately prominent and pretty regularly placed lines of growth.

The hinge plate is wide; chondophore deep and slightly roofed; left cardinal is somewhat broken, but the remaining portion shows that the arms were of nearly equal length and that the tooth was situated medially upon the hinge plate; arms of the right cardinal heavy, the anterior one not confluent with, nor in the same plane with the ventral lamina; laterals but imperfectly preserved, the anterior one arising from the ventral edge of the hinge plate, and distant from and not in alignment with the anterior cardinal arm; laminae short and low, the posterior ventral one being the largest; ventral sinus is restricted by an abrupt inbending of the ventral margin of the hinge plate. Pallial sinus extends to the middle of the shell. The dimensions of the type obtained by Gabb from the vicinity of Martinez, Contra Costa County, California, were given as equivalent to: length, 69 mm., height, 59 mm., convexity,

15 mm. Those of the plesiotype are: length, 74 mm., height, 53 mm., convexity, 15.5 mm.

Neither the type nor any specimens that were labeled by the members of the State Geological Survey are known to exist. Several specimens from the general region from which the type was obtained appear to satisfy the description of this species as given by Gabb. One of these has been made the plesiotype of this species.

Although the ratio of the height to the length of this species is quite variable, this form is quite readily separable from other known mactrine species. Certain specimens might possibly be confused with a young specimen of *S. catilliformis*, but the lack of the characteristic posterior flexure of that species and the widely different type of dentition easily characterizes Gabb's species.

Occurrence.—Oligocene: Agasoma gravidum zone, Mount Diablo region, California.

SPISULA ABSCISSA (Gabb)

Plate 23, figure 4, and plate 24, figure 2

Schizodesma abscissa Gabb, Pal. Cal., vol. 2, p. 20, pl. 4, figs. 34 and 34a, 1869.

This species was described by Gabb as follows:

Shell large, thick, irregularly subquadrate; beaks large, prominent, pointed forwards, nearly central; anterior end obliquely truncated; base broadly rounded; posterior end very strongly and abruptly truncated, the truncation ending at an angular ridge which passes from the beaks to the posterior basal angle. Surface marked by rough irregular lines of growth. Hinge composed of large robust teeth; lateral teeth long and thick.

A specimen obtained from the vicinity of San Pablo Bay, California, appears to satisfy the requirements of the description of this species as given by Gabb. The type being lost, a specimen from University of California Locality 1608, is here taken as the plesiotype.

The hinge plate is rather broad, chondophore wide and deep, slightly overhung by the arm of the cardinal; left cardinal rather small, arms of equal length, extending ventrally to about the middle of the hinge plate; laterals long and rather thin, smooth, flat-topped, distant from the beak, the anterior one not reaching to the arm of the cardinal. Hinge of right valve unknown. The dimensions of the type as measured on the original figure are: length, 100 mm., height, 98 mm., convexity, 36 mm.

This species is extremely variable in general shape. It is typically more quadrate in outline than the associated mulinoid species, and it lacks the prominent beaks of these species, besides differing in details of the hinge. The type of this species was obtained from the indefinite locality of San Pablo Bay, Contra Costa County, California.

Occurrence.—Miocene: Lower San Pablo group, Mount Diablo region, Contra Costa County, California.

SPISULA ALBARIA (Conrad)

Plate 24, figure 1; plate 25, figures 3 to 8

Mactra albaria Conrad, Am. Jour. Sci., 2d. ser., vol. 5, p. 432, fig. 4, 1848; Dall, U. S. Geol. Surv. Prof. Paper 59, p. 150, fig. 4, 1909 (reprint); Arnold, U. S. Geol. Surv. Bull. 396, p. 30, pl. 19, fig. 4, 1909.

Mactra diegoana Conrad, House Doc. no. 129, p. 14, 1855; Pacific R. R. Repts., vol. 5, p. 325, pl. 5, fig. 45, 1855.

Standella planulata, Gabb, Pal. Cal., vol. 2, p. 91, 1869; not of Conrad 1837.

Spisula albaria (Conrad), Dall, U. S. Geol. Surv. Prof. Paper 59, p. 130, pl. 10, fig. 1, 1909.

? *Spisula precursor* Dall, U. S. Geol. Surv. Prof. Paper 59, p. 131, pl. 14, fig. 10, 1909.

Conrad described this species as follows:

Triangular, ventricose; beaks medial; umbonal slope angulated; anterior and posterior margins nearly equally oblique; posterior extremity truncated, direct; basal margins regularly curved.

The hinge of a specimen from the Merced group, near Capitola, Santa Cruz County, California, is best known and will serve as the basis for the description.

Hinge plate wide, chondophore oblique, rather deep and partially roofed by an accessory; spur distinct in most specimens; cardinals large, heavy, arms widely diverging; dorsal edge of the left cardinal is fused to the margin of the shell; ventral sinus somewhat excavated; right cardinal prominent, anterior arm short, posterior arm heavy, extending in a straight line from near the beak to the ventral margin of the plate; anterior lateral short, top evenly rounded, smooth, distant from and in alignment with the anterior arm of the cardinal; posterior lateral long, slightly higher than the margin of the shell arising from the ventral edge of the hinge plate; laminae long, the ventral ones also arising from the edges of the plate; the dorsal ones are small, arising from the

margin of the plate. Pallial sinus deep, rounded, not extending in front of the vertical of the beaks. The dimensions of the type as inferred from the original cut, are: length, 45 mm., height, 35 mm.

The type of this species was collected by Townsend and described by Conrad, together with other fossil material from a locality on the Columbia River, near Astoria. Gabb confused this variable species with *Spisula planulata*. The species was recognized by Arnold in the Lower Etchegoin formation of the Coalinga District, California. Arnold's figure of the form differs considerably from that of the type and also from that given by Dall from the Empire formation of Coos Bay, Oregon.

These three forms represent but three different shapes assumed by this species. In some collecting localities these forms occur together, while in others one form or another predominates. There appears to be no general type found in the San Pablo group that is not equally well represented by specimens from the Merced. A comparison of the hinges of these different specimens shows a remarkable uniformity as regards the dental armature.

Spisula albaria is closely related to *S. albaria* var. *ramonensis*, from which it differs in being typically more elongate, with a narrower hinge plate and shorter laterals, which are more intimately connected with the cardinal arm. It differs from *S. selbyensis* in being more nearly equilateral, in its wider hinge plate, less compressed left cardinal, shorter laminae and in the less intimate connection between the anterior ventral lamina and the cardinal arm.

The type of *S. precursor* was obtained from the Empire Formation of Coos Bay, Oregon. The outline of this species might easily fall within the range of the shape-variation of *S. albaria*. It is therefore considered as probably representing that species.

Occurrence.—Pliocene: Merced group. Miocene: San Pablo group.

SPISULA ALBARIA (Conrad) var. RAMONENSIS, n. var.

Plate 23, figure 5; plate 25, figures 1 and 2

Shell medium-sized, inequilateral, somewhat compressed; height nearly equal to that of the length; umbones rather prominent, sharply pointed; shell smooth except for an occasional heavy incremental line of growth; anterior dorsal area excavated below the

umbones; anterior dorsal edge straight; posterior dorsal edge convex; sloping regularly to the broadly rounded extremity; base arcuate. Hinge plate wide, chondophore deep, not roofed; left cardinal prominent, extending from the dorsal to the ventral margin of the plate; arms of equal length, heavy, the posterior one bearing an indistinct lamella; ventral sinus narrow; laterals long, the anterior one arising from the ventral edge of the plate; it is nearly flat-topped, and is not in alignment with, nor reaching to the anterior arm of the cardinal. The pallial sinus, as well as the hinge of the right valve is unknown. The dimensions of the type are: height, 54.5 mm., convexity, 17.5 mm. Those of the cotype are: length, 60 mm., height, 50 mm., convexity, 13 mm.

This variety is closely related to *S. albaria*, being perhaps the progenitor of that species; it varies considerably as regards general shape; elongate specimens are not separable upon the basis of shape alone from the typical species. Since the great majority are more ovate, and since the hinges of those specimens observed are different from *S. albaria*, it appears to be worthy of varietal rank. It differs from Conrad's species in that the hinge plate is relatively wider, the left cardinal is heavier and the laterals are longer and more distant from the cardinal arm.

Occurrence.—Oligocene: Agasoma gravidum zone, Mount Diablo region, California.

The type of this variety was obtained from University of California Locality 1687. It was collected by R. E. Dickerson, who described the locality in the following words: "To the north of the road leading to Tice Valley, west of the first "a" in "San Ramon," Concord sheet, Contra Costa County, California.

SPISULA SELBYENSIS, n. sp.

Plate 26, figures 2a, 2b and 3

Shell inequilateral, somewhat ventricose; umbones rather prominent, adjacent, generally situated posterior to the middle of the shell; area below and anterior to the beaks strongly excavated; anterior dorsal edge nearly straight, sloping regularly to the broadly rounded anterior extremity; posterior dorsal edge broadly rounded, meeting a slight truncation at the base; base arcuate; surface marked by a varying number of incremental lines of growth; hinge plate very narrow; chondophore deep and somewhat com-

pressed; left cardinal high, arms of nearly equal length, not widely diverging; this tooth extends from the dorsal to the ventral margin of the hinge plate; ventral sinus very restricted; laterals long, low, round-topped, arising from the ventral margin of the plate; base of the anterior lateral not reaching to the cardinal arm; right cardinal well developed, with a heavy anterior arm, which is closely appressed to the margin of the shell; posterior arm also heavy, reaching to the ventral border of the plate; anterior ventral lamina long, in the same plane with, and joining the anterior cardinal arm by a low ridge. The dimensions of the type are: length, 29 mm., convexity, 10 mm.

This species resembles *S. albaria* in general outline, but it differs from that species in that it is generally more inequilateral and more elongate, with a narrower hinge plate, and more compressed left cardinal. The length of the laminae and the close relationships between the anterior ventral lamina and the cardinal arm also characterize this species.

The shape of this species is exceedingly variable. The beaks are in some specimens anterior to the middle of the shell, while in others from the same collecting locality they are posterior to that line. This variation has already been discussed at some length in another portion of this paper (page 268).

The type was obtained from University of California Locality 1352. This locality was described by J. C. Merriam under number 360 as follows: "One-third of a mile south-west of Vallejo Junction, in a bluff close to the railroad track at the lowest Miocene contact with the Martinez, Napa sheet."

Occurrence.—Miocene: Monterey group, Arca montereyana zone.

SPISULA PLANULATA (Conrad)

Plate 16, figures 3a, 3b and 3c

Mactra planulata Conrad, Jour. Acad. Nat. Sci. Phila., vol. 7, pt. 2, p. 240, 1837; (not *M. planulata* of Carpenter nor *Standella planulata* of Gabb, Cooper nor Stearns).²³

Spisula planulata (Conrad), Conrad, Am. Jour. Conch., vol. 3, appendix, p. 45, 1868; Dall, Nautilus, vol. 8, p. 40, 1894; Proc. Royal Soc. Canada, 2d. ser., vol. 1, p. 48, 1894.

The general shape of this shell is somewhat like that of *S. falcata*,

²³ These authors confused several species, notably *S. albaria*, *S. planulata* and *S. voyi*, therefore their citations have but little value.

but it differs from that species in being flatter and in being more inequilateral. If the hinges are compared, it is found that the arms of the left cardinal of *S. planulata* are of nearly equal length whereas those of *S. falcata* are markedly uneven. The length of the type is equivalent to 38 mm. The dimensions of the specimen figured in this paper are: length, 45 mm., height, 32 mm., convexity, 7 mm.

The type of this species was described from a Recent specimen obtained from Santa Barbara, California.

Occurrence.—Recent: Monterey to San Diego, California (Dall).

SPISULA MERRIAM, n. sp.

Plate 27, figures 3a and 4

Shell small, trigonal, equivalve nearly equilateral, ventricose, ornamented by numerous fine concentric ridges, which are more pronounced and less numerous on the anterior and posterior dorsal areas than upon the other portions of the shell; beaks moderately prominent, anterior dorsal area limited by a distinct ridge extending from the umbo to the anterior extremity; the margin of this area is nearly straight; posterior dorsal slope slightly convex, limited by an indistinct ridge which extends from the beak to the base of the shell; anterior extremity more sharply pointed than the posterior; base very broadly rounded. Hinge plate relatively broad, chondophore oblique, shallow, apically roofed by a broad flat spur; left cardinal prominent, high, arms broad, extending from the dorsal to the ventral margin of the plate; ventral sinus narrow, flat; right cardinal with a prominent anterior arm and a well-developed, although relatively thin posterior arm; laminae long, distant from the beaks; anterior lateral formed from the margin of the plate, top rounding, distant from the anterior arm of the cardinal; posterior lateral also with a rounding top, dorsal and ventral slopes nearly equal; anterior ventral lamina formed from the upturned edge of the hinge plate, not confluent with the anterior cardinal arm; anterior dorsal scarcely developed, considerably smaller than the corresponding posterior one. The dimensions of the type are: length 18.6 mm., height 14.2 mm., convexity 4 mm.

This trigonal species might be confused with the Cretaceous form, *S. ashburnerii*. It differs from that species in being less tumid, in being more strongly sculptured and in the possession of the posterior arm of the right cardinal.

The type of this species was obtained from University of California Locality 672. R. E. Dickerson described this station as follows: "Coalinga Quadrangle, Fresno County, California, SE $\frac{1}{4}$ of NW $\frac{1}{4}$ of Sec. 24, T 18 S, R 14 E, Parson's Peak, in Tejon white sandstones. About ten feet below white shale."

Occurrence.—Eocene: Tejon series, Parson's Peak and the south side of Mount Diablo, California.

SPISULA ACUTIROSTRATA, n. sp.

Text figure 2a and b

Shell medium sized, slightly ventricose, trigonal in outline; inequilateral; sculptured by indistinct incremental lines of growth; beaks prominent, strongly incurved and acutely pointed; posterior

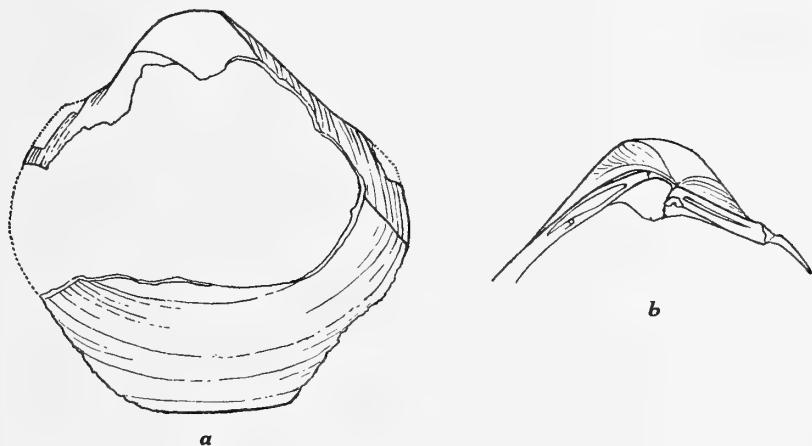


Fig. 2. *Spisula acutirostrata*, n. sp. 2a, type specimen; 2b, left hinge. Both figures natural size.

dorsal margin somewhat convex; anterior margin also slightly convex. Anterior extremity of the cotype produced and slightly truncated, while the posterior end is more evenly rounded; ventral margin arcuate. Escutcheon of the type specimen impressed and broad; posterior dorsal area limited by a prominent angulation or ridge which extends from the umbo to the posterior extremity. Hinge plate rather wide; chondophore deep, quite broad; left cardinal broken, but it was apparently low, heavy and not extending to the ventral margin of the plate. No accessories nor spur observable.

Anterior lateral low, long; posterior lateral also rather low. Hinge of right valve unknown. The dimensions of the type are: height, 55 mm., length, 53 mm., convexity, 17 mm.

This is the largest of the known West Coast Eocene species. It is characterized by its pronounced posterior ridge, its escutcheon and its small heavy cardinal. It differs from *S. merriami*, which it superficially resembles, in its more massive cardinal, more prominent posterior ridge and in the lack of pronounced ribs.

The type was obtained from University of California Locality 463. The following is the description given by R. E. Dickerson: "SE $\frac{1}{4}$ of NW $\frac{1}{4}$ of Sec. 32, T 10 N, R 20 W. On a branch cañon of Salt Creek, 150 feet above the bottom. Mount Pinos sheet, California."

Occurrence.—Eocene: Tejon series.

SPISULA BREVIROSTRATA, n. sp.

Plate 28, figures 1a, 1b and 2

Shell medium-sized, compressed, equilateral, umbones small, adjacent; anterior dorsal edge sloping in a nearly straight line to the rather attenuated anterior extremity. A fairly distinct ridge, extending from the umbones to the anterior extremity, limits a depressed area on the anterior margin of the shell; posterior dorsal edge very slightly convex, sloping regularly to the broadly rounded extremity; base arcuate. Hinge plate relatively wide; chondophore very shallow, triangular in shape, probably overhung by a small spur; left cardinal large, not overhanging the resilifer, situated ventrally on the hinge plate; arms of equal length, their ventral edges rounded; laterals high, short; anterior one round-topped and shorter than the posterior one, which is acutely pointed; dorsal base of the anterior lateral is close to, but slightly dorsal to, the anterior arm of the cardinal. Pallial line distant, pallial sinus reaching nearly to the middle of the shell. Hinge of the right valve unknown. The dimensions of the type are: length, 78 mm., height, 60 mm., convexity, 15 mm.

This species has been confused with *S. falcata*, from which it differs in being relatively higher and in possessing a large left cardinal the arms of which are of equal length.

The type of this species was collected by Bruce Martin at University of California Locality 1875. Martin described this station

as follows: "Along the east bank of Eel River one mile north of Scotia, Humboldt County, California."

Occurrence.—Pliocene: Wildcat group, Humboldt County, California.

Subgenus *Symmorphomactra* Dall, 1894

Type *Mactra falcata* Gould

Cardinals prominent, thin, posterior arm of the cardinal tooth overhangs the chondophore; accessories on each arm; hinge plate flat.

SPISULA FALCATA (Gould)

Plate 26, figures 1a, 1b and 1c

Mactra falcata Gould, Proc. Boston Soc. Nat. Hist., vol. 3, p. 216, 1849.

Standella falcata (Gould), Gabb, Pal. Cal., vol. 2, p. 92, 1869.

Spisula falcata (Gould), Dall, Nautilus, vol. 8, p. 41, 1894.

The shell of this species is small, subtrigonal, slightly inequilateral. The beaks are small, sharply pointed and situated a little posterior to the middle of the shell; anterior dorsal edge nearly straight; posterior edge somewhat convex; base gently arcuate; anterior extremity somewhat attenuated, posterior evenly rounded. Hinge plate rather wide, chondophore shallow, apically roofed and overhung by the posterior arms of the cardinals; spur prominent; left cardinal fragile, compressed, the anterior arm much longer than the posterior, which markedly overhangs the resilifer; anterior arm of the right cardinal the heavier, bearing anteriorly a small lamella; laterals rather short, smooth, arising from the ventral margin of the hinge plate at a point distant from the umbones; laminae short, low and rather heavy, the dorsal ones arising from the dorsal shell margin; a prominent lamella occurs in the left valve between the anterior lateral and the cardinal, being parallel to and nearly equal in height to, the latter. Pallial sinus shallow, irregularly rounded. The dimensions of the specimen figured in this paper are: length, 43 mm., height, 31 mm., convexity, 7 mm.

The Recent specimens studied show but little variation in general shape. This species superficially resembles *S. brevirostrata*, from which it has been recently separated. It differs from that new species in being more elongate and in possessing the compressed left cardinal characteristic of the subgenus *Symmorphomactra*, also in

many minor details of the hinge. It might also be mistaken for *S. planulata*, from which it differs in being more ventricose and more equilateral, besides possessing a different type of left cardinal.

The type of this species was obtained in Puget Sound.

Occurrence.—Recent: Alaska to San Diego, California (Dall). Pleistocene: San Pedro, San Diego (Arnold). Pliocene: Etchegoin (Arnold). Miocene: San Pablo (?) (Clark).

Subgenus *Cymbophora* Gabb, 1869

Type *Mactra ashburnerii* Gabb

Hinge heavy, resilium with convex ends; right cardinal tooth lacking the posterior arm; delicate, nearly at a right angle with the anterior margin of the chondophore; left cardinal slender; laterals large and robust.

SPISULA ASHBURNERII (Gabb)

Plate 26, figures 4 and 5

Mactra ashburnerii Gabb, Pal. Cal., vol. 1, p. 153, pl. 22, fig. 127, 1863; Arnold, U. S. Geol. Surv. Bull. 396, p. 104, pl. 1, fig. 4, 1909.

Cymbophora ashburnerii (Gabb), Pal. Cal., vol. 2, p. 181, pl. 29, fig. 69, 1869.

Spisula ashburnerii (Gabb), Dall, Trans. Wagner Inst. Sci., vol. 3, pt. 4, p. 879, 1898.

This species was described by Gabb as follows:

Shell moderate in size, subtrigonal; base broadly and regularly convex; beaks central, slightly inclined forwards; posterior cardinal margin sloping, straight, slightly convex; anterior faintly excavated; some specimens show an umbonal angle well marked, while in others it is nearly or entirely obsolete. Surface variable; specimens from some localities showing a large number of regular, nearly uniform, rounded, concentric ribs;²⁴ while those found at other places have these ribs few, entirely absent, or only represented by fine lines of growth.

Hinge plate wide, chondophore spoon-shaped, shallow, with raised margins; left cardinal slender, arms of equal length, situated medially on the hinge plate and not overhanging the pit; right cardinal without a posterior arm, anterior one well-developed; laterals heavy, distant from the umbones; laminae prominent, the dorsal ones arising from the dorsal margin of the shell. The dimensions of the

²⁴ These characters were based upon specimens afterwards recognized as belonging to a distinct species, *S. gabbiana*.

specimen figured in this paper are: length, 21 mm., height, 15.5 mm., convexity, 5 mm.

This species was made the basis of the genus *Cymbophora*, which according to Dall should have only subgeneric value. This trigonal species lacks the pronounced radial ribbing of the closely related form *S. gabbiana*, with which it was confused by both Gabb and Whiteaves.

The type of this species was obtained from Pence's Ranch, Butte County, California.

Occurrence.—Cretaceous: (?) Horsetown (Diller); common in the upper Chico of the coast region.

SPISULA GABBIANA (Anderson)

Plate 27, figure 2

Mactra gabbiana F. M. Anderson, Proc. Cal. Acad. Sci., 3rd ser. vol. 7, p. 74, pl. 7, fig. 156, 1902.

This species was described by Anderson as follows:

Shell moderate in size, somewhat resembling *M. ashburnerii* Gabb, but generally with a heavier shell, and more strongly grooved concentrically; umbonal angle strongly marked, especially near the base; anterior surface flattened but not excavated.

The hinge of this species is but imperfectly known. One specimen from Chico Creek, California, which undoubtedly belongs to this species shows a well-developed anterior arm to the right cardinal, but no trace of a posterior arm. Another specimen of the left valve has a rather shallow chondophore bounded by raised margins, characteristic of the subgenus *Cymbophora*. The cardinal is prominent, massive, extending ventrally nearly across the hinge plate; the arms are very thick; anterior lateral apparently fused to the dorsal side of the anterior arm of the cardinal; posterior lateral long, but little higher than the adjacent shell margin. Pallial sinus rather shallow, broadly rounded. Its dimensions, as measured upon the figure of the type are: length, 44 mm., height, 33 mm.

This species differs from *S. ashburnerii* in being typically much larger and more heavily ribbed and less angulated posteriorly.

The type of this species was obtained from Henley Creek, Siskiyou County, California.

Occurrence.—Cretaceous: Chico of Henley Creek, Chico Creek and numerous other Chico localities of California.

SPISULA CHICOENSIS, new name

Plate 27, figures 6 and 7

Lutraria truncata Gabb, Pal. Cal., vol. 1, p. 154, pl. 22, fig. 128, 1863.*Spisula truncata* (Gabb), Dall, Trans. Wagner Inst. Sci., vol. 3, pt. 4, p. 879, 1898.

This species was described by Gabb as follows:

Shell thin, compressed, somewhat elongated, length compares with the breadth as about four to three; beaks nearly central, small, acute and slightly inclined forwards; anterior cardinal margin slightly sinuous, posterior convex, nearly straight; anterior end rounded; posterior obliquely truncated, gaping. Surface marked by faint irregular lines of growth.

Only part of the hinge of the left valve is known. Hinge plate wide, resilifer very narrow, long, with raised margins, which appear as a prominent toothlike ridge arising from the posterior margin of the chondophore; resilifer not roofed nor overhung by the cardinal arm; cardinal very prominent, high, arms of equal length, extending nearly across the hinge plate; ventral sinus excavated; anterior lateral partially destroyed; it is high and arises from the ventral margin of the plate, extending nearly to the dorsal margin of the shell, at some distance from the arm of the cardinal; posterior lateral short, nearly parallel to the ridge bounding the chondophore. Pallial sinus unknown. The dimensions, as inferred from the figure of the type are: length, 50 mm., height, 35 mm. A specimen from the type locality measures: length, 49 mm., height, 36 mm., convexity, 8 mm.

Spisula chicoensis is quite constant in general shape, which strongly suggests that of a *Tellina*. This form would not easily be confused with any known coast Mactrinae.

The specific name *truncata* was used by Montagu in 1808 for a species that later became known as *Hemimactra truncata*.²⁵ It is necessary to rename Gabb's species, because the genus *Hemimactra* has since been reduced to the rank of a subgenus under *Spisula*.

This species was described from specimens obtained from Pence's ranch, (Pentz Post Office) Butte County, California.

Occurrence.—Cretaceous: Chico, Pence's ranch, Chico Creek, and Mineral Slide, Butte County, California (Gabb).

²⁵ Conrad, T. A., Am. Jour. Conch., vol. 3, appendix, p. 33, 1868.

SUBGENERIC POSITION UNCERTAIN

SPISULA CALLISTAEFORMIS Dall

Spisula callistaeformis Dall, Harriman Ala. Exped., vol. 4, p. 108, pl. 9, fig. 9, 1904.

Dall described this species as follows:

Shell elongate, recalling *Macrocallista* in outline, the anterior end slightly shorter, attenuated in front, arcuate below, wider and rounded behind with an obscure radial ridge near the dorsal slope; disk slightly flattened, concentrically striated, the beaks pointed and moderately elevated. . . . This species is rather abundant and uniform. The pallial sinus is deep and free from the pallial line for most of its length below. The dimensions of the holotype specimen are: length, 50 mm., height, 28 mm., convexity, 8 mm.

This species is based upon fossil specimens obtained from the eastern side of Chichagof Cove, Alaska. The holotype was deposited in the United States National Museum under the catalogue number 164882.

Dall suggests that this species may belong to the subgenus *Cymbophora*. Specimens of this species have not been available for study and therefore its subgeneric position is still uncertain.

Occurrence.—Eocene: Upper Stepovak series, Alaska (Dall).

SPISULA COALINGENSIS (Arnold)

Plate 27, figure 8

Mactra coalingensis Arnold, U. S. Geol. Surv. Bull. 396, p. 71, pl. 25, fig. 4, 1909.

This species was described by Arnold as follows:

Shell averaging about 52 millimeters in width, equivalve, trigonal in outline, rounded behind, slightly attenuated in front; beaks not prominent, situated slightly anterior to middle of shell; anterior superior margin only slightly excavated in front of beaks, nearly straight to anterior extremity, which is quite abruptly truncated; posterior inferior margin slightly curved, and merging imperceptibly into the regularly convex posterior extremity; basal margin moderately curved. Hinge and cartilage areas concealed in the type, but believed to be similar to *M. falcata* Gould. The dimensions of the type are: length, 65 mm., height, 52 mm.

Although several specimens that agree with the above description have been collected from the Etchegoin of the Coalinga District, none has been found that shows the hinge. The general shape and

its possible affinities with *S. falcata* are the bases for the change of genus as given above.

This species is larger, relatively broader and more trigonal than *S. falcata*. It differs from *S. brevirostrata* in being more nearly equilateral and from *S. albaria* in being less ventricose.

The type of this species was obtained in Waltham Creek Valley, south of Coalinga, Fresno County, California. It was deposited in the United States National Museum under the catalogue number 165513.

Occurrence.—Pliocene: Etchegoin formation, Coalinga District, California (Arnold).

SPISULA LENTICULARIS (Gabb)

Hemimactra lenticularis Gabb, Pal. Cal., vol. 2, p. 19, pl. 4, fig. 3, 1869.

This species was described by Gabb as follows:

Shell large, flattened, thin, inequilateral, irregularly subquadrate; beaks eccentric, large, slightly curved forwards and inwards; anterior end broadly concave below the beaks and convex below; base and posterior end regularly convex; cardinal margin sloping nearly straight. Hinge teeth slender. Pallial sinus moderately deep, round at the base. Surface marked by irregular lines of growth. The dimensions of the type are equivalent to: length, 96 mm., height, 106 mm., convexity, 22.8 mm.

The type of this species is apparently lost. The form will be listed as a *Spisula*, since the genus *Hemimactra* as used by Gabb has been reduced to the rank of a subgenus. Fragments of a large form which may be referable to this species, have been collected from the region of the type locality.

The type locality of this species is given as "South of Martinez, Contra Costa County California."

Occurrence.—Miocene: Contra Costa County, California (Gabb).

SPISULA SISQUOCENSIS Arnold

Spisula sisquocensis Arnold, Smithsonian Misc. Coll., vol. 50, p. 437, pl. 56, fig. 1, 1907.

This species was described by Arnold as follows:

Shell averaging about 120 millimeters in longitude, subtrigonal in outline, equivalve, inequilateral, ventricose; base regularly arcuate; beaks anterior, prominent, bent forward, protruding beyond periphery of shell; anterior

end shorter and narrower than the posterior, which is evenly rounded; area in front of beaks depressed concavely as a whole, but slightly elevated at margin, this condition when the two valves are together, suggesting a large lunule with a slightly raised ridge running down the middle; posterior margin becomes more and more arcuate as extremity is approached, sculpture consisting of numerous fine incremental lines, some of which are more prominent than the great majority, these more prominent ones giving a slightly irregular surface to the shell. Hinge and interior unknown, but probably quite similar to *S. hemphillii*. The dimensions of the type are given as: length, 120 mm., height, 85 mm., convexity, 28.5 mm.

This species was found associated with *S. catilliformis* var. *alcatrazensis* Arnold. Specimens of this species have not been available for study, therefore its subgeneric relationships cannot be stated.

The type of this species was obtained from the Fernando formation from the Alcatraz asphalt mine, near Sisquoc, Santa Barbara County, California. It was deposited in the United States National Museum under catalogue number 165292.

Occurrence.—Pliocene: Fernando formation (Arnold).

SPISULA TEJONENSIS, n. sp.

Plate 27, figure 5

Shell small, elongate, equivalve and nearly equilateral; umbones not prominent, adjacent; anterior dorsal edge slightly concave immediately under the beaks, but then becoming straighter until the rather arcuate anterior extremity is reached; posterior dorsal edge slightly convex; posterior extremity a little more rounded than the anterior; base broadly and evenly rounded; dorsal area limited by an indistinct umbonal ridge, extending from the beaks to the posterior extremity of the shell; this posterior dorsal area is marked by fine regularly disposed concentric ridges, which do not typically extend beyond the slightly carinated umbonal ridge. Interior unknown. The dimensions of the type are: length, 22.5 mm., height, 16.5 mm., convexity, 6 mm.

It was with some hesitation that this form was described without first studying the hinge. Its distinctive shape and its frequent occurrence in the California Eocene appear to justify the naming of this form.

This species is distinguished from *S. merriami* by its less ventricose and more elongate shape, together with its less pronounced concentric sculpture.

The type of this species was obtained at University of California

Locality 785, which is described by R. E. Dickerson as follows: "Vicinity of Lower Lake, Lake County, Tejon Group. NW $\frac{1}{4}$ of SE $\frac{1}{4}$ of Sec. 6, T 13 N, R 6 W, in a west gully near hill top. Elevation 1750 feet."

Occurrence.—Eocene: Tejon group, Lower Lake and Mount Diablo, California.

Genus MULINIA Gray, 1837

Type *Macra typica* Gray

Ligament and resilium not separated, entirely internal; teeth not concentrated; laterals subequal; valves not gaping. Pallial sinus small and short.

MULINIA DENSATA Conrad

Plates 29, 30, 31, 32 and 33

Mulinia densata Conrad, Proc. Acad. Nat. Sci. Phil., December 1856, p. 313; Pacific R. R. Repts., vol. 6, p. 71, pl. 3, fig. 12, 1857; Gabb, Pal. Cal., vol. 2, p. 19, pl. 5, fig. 35, 1869 (*in part*); Arnold, U. S. Geol. Surv. Bull. 396, p. 55, pl. 21, fig. 3, 1909.

Cardium gabbii Rémond, Proc. Cal. Acad. Sci., vol. 3, p. 13, 1863.

Pseudocardium gabbii (Rémond), Gabb, Pal. Cal., vol. 2, p. 21, pl. 6, figs. 45a, b and c, 1869.

Mulinia oregonensis Dall, U. S. Geol. Surv. Prof. Paper 59, p. 132, pl. 9, figs. 2 and 3 and pl. 13, fig. 5, 1909.

This species was described by Conrad as follows:

Subovate, ventricose, thick, very inequilateral; posterior side very short comparatively, contracted; extremity subtruncated, much above the line of the base; posterior basal margin very oblique and contracted; anterior end obliquely truncated; anterior basal margin rounded; summits prominent, distant; external teeth very robust and prominent; inner margin entire. The length of the type is equivalent to 73 mm. The height as measured on the original figure is 58 mm.

Conrad's original description of *Mulinia densata* was supplemented by a figure which was later criticized by Gabb, who contended that the species was based upon a contorted specimen. Gabb redescribed the species, basing his description upon a specimen obtained from near San Pablo Bay, California. He appeared to base his conclusions upon the general shape of the shell, for he failed to note that Conrad's species was described as having "very robust

and prominent teeth," whereas his San Pablo specimen had a small hinge with slender teeth.

Rémond described a form from the Miocene of Walnut Creek, Contra Costa County, California, under the name of *Cardium gabbii*, which later served as the type of Gabb's genus *Pseudocardium*. Arnold, after making a study of the forms from the Coalinga District, California, came to the conclusion that *Pseudocardium gabbii* and *Mulinia densata* were identical. He also described a form from the Vaqueros under the name of *M. densata* var. *minor*.

Another form was described from the Empire formation of Coos Bay, Oregon, under the name of *Mulinia oregonensis* Dall. This is based largely upon the rugose character of the shell and its narrow shape. Both of these characters fall within the range of variation of *M. densata*.

Related forms were reported from the Miocene of Washington. One was given specific rank while the others were listed as varieties of *Pseudocardium gabbii*. The types of these four forms have been studied and their relationships may now be more clearly shown.

Specimens representing these different forms from a large number of localities have been studied from the standpoint of the general shape and from that of the dental armature. The conclusions of these studies are that these species and varieties as given above in the synonymy are not separable into distinct species or even varieties. The extremes in a suite from one collecting locality or series made up of specimens from different localities and horizons are often markedly different, but an attempt to so define the extremes in terms that will serve to separate the middle members has been unsuccessful.

The figures show a few picked specimens of series showing the relative prominence of the umbones, (plate 25), the general shapes, (plate 26) and the characters of the dentition (plate 28). Plate 26 shows the amount of variation commonly found in the more ventricose forms. This series represents specimens from a single collecting locality, showing how the short tumid form grades into the elongate flat type. Specimens that appear to have lived under adverse conditions are shown on plate 27. The narrow, crude valves of this series are not distinguishable from *Mulinia oregonensis* of Dall, which is here considered synonymous with *M. densata*.

Not only are there shape gradations between the typical and

the *Pseudocardium* form, but the hinges of the two are to all essentials identical.

The differences of the hinge of the left valve, as figured on plate 29 are those of varying thicknesses of the laterals and the arms of the cardinals. This thickening appears to be a function of the shortening of the hinge line of the more ventricose forms. These dental characters grade insensibly along with the changing shape of the shell from that of the elongate typical form with its long laterals to the *Pseudocardium* form with its robust teeth.

It is worthy of mention that in the region of Mount Diablo, California, the great majority of specimens belong to the ventricose type, whereas at a higher horizon in the Coalinga District these *Pseudocardium* forms are the exception. This might suggest that these two forms represent two parallel races, one of which became dominant during the San Pablo, while the typical form reached its maximum in the Etchegoin; and that they did not diverge enough from the parent stock to be easily classified as definite species.

The hinge plate of *Mulinia densata* is rather wide; chondophore deep; roofed apically and overhung by a lamella in the left valve; the left cardinal prominent, often heavy, the arms of equal width, and often fused together in the *Pseudocardium* forms, producing a triangular block-tooth and varying in this respect to a condition where the arms are clearly defined; the arms of the cardinal reach ventrally nearly across the hinge plate; the anterior arm of the right cardinal is more prominent than the posterior one; laterals of unequal length; distant from the beaks, being relatively short and heavy in the more ventricose forms; anterior lateral nearly in alignment with the cardinal arm, but distant from that tooth; laminae heavy, the anterior ventral one is in line with the cardinal arm; dorsal laminae small, arising from the dorsal margin of the shell. Pallial sinus shallow, broadly rounded. *Mulinia densata* is separable from *M. pabloensis* by the lack of striations on the lateral teeth; from *M. alta* by its much heavier left cardinal and wider hinge plate; and from *M. undilifera* by its narrower hinge plate and more delicate teeth.

Conrad's type was obtained from the vicinity of Santa Barbara, California.

Occurrence.—Pliocene: Etchegoin. Miocene: San Pablo, Upper Monterey.

MULINIA DENSATA Conrad var. MINOR Arnold

Mulinia densata, var. *minor* Arnold, U. S. Geol. Surv. Bull. 396, p. 54, pl. 5, fig. 6, 1909.

This variety is characterized by its smaller size, and its more inequilateral form than the typical *M. densata*. Its hinge is unknown.

The type of this variety was obtained from Jasper Creek, Fresno County, California. It was deposited in the United States National Museum under catalogue number 165601. The dimensions as measured on the original figure are: length, 42 mm., height, 36 mm.

Occurrence.—Pliocene: Etchgoin (Arnold). Miocene: Vaqueros (Arnold).

MULINIA ALTA (Weaver)

Pseudocardium gabbi (Rémond) var. *altum* Weaver, Wash. State Geol. Surv., Bull. 15, p. 68, pl. 7, fig. 69, 1912.

P. gabbi, var. *elongatum* Weaver, op. cit., p. 68, pl. 10, fig. 78.

P. gabbi, var. *robustum* Weaver, op. cit., p. 69, pl. 7, fig. 68.

This variety was described by Weaver as follows:

This variety is large, somewhat compressed; beaks moderately high but not especially prominent for the genus. Anterior and posterior margins have steep slopes, the latter being more pronounced. The altitude is much greater in proportion to the longitude than in the case of the other varieties. The dimensions of the type are: length, 75 mm., height, 78 mm., convexity, 30 mm.

The type specimens of *Pseudocardium gabbii* var. *altum*, *P. gabbi* var. *elongatum* and *P. gabbii* var. *robustum* were kindly loaned the writer by Dr. C. E. Weaver of the University of Washington.

The hinges of these three type specimens have been exposed and their relationships may now be definitely stated. A comparison with typical specimens of *Mulinia densata* from California show that, although the general shape of these Washington forms falls within the range of the variation of the typical species, the dental armature possesses differences of at least varietal value.

The shapes of the three forms are somewhat different, but the hinges are nearly identical, varying only as one individual varies from another. The three specimens show the left cardinals, two of them show the anterior lateral but in none of them is the posterior lateral preserved.

The hinge plate is narrow, the chondophore deep, oval, apically roofed, not overhung by an accessory; cardinal tooth very small, high, situated medially on the hinge plate, arms of equal length, thick, anterior lateral long, low, reaching nearly to the arm of the cardinal. Hinge of the right valve and the pallial sinus unknown.

This species differs from *Mulinia densata* in its narrower hinge plate and much smaller cardinal tooth. It is separable from *Mulinia pabloensis* by the absence of striations on the lateral teeth, and from *M. undilifera* by its much more delicate teeth.

The type of this variety was obtained from Miocene strata near Elmer, Chehalis County, Washington.

Occurrence.—Miocene: Upper Miocene, Elmer, and Satsop, Chehalis County, Washington (Weaver).

MULINIA UNDILIFERA (Weaver)

Plate 34, figures 1a, 1b, 2 and 3

Pseudocardium gabbi (Rémond) var. *undiliferum* Weaver, Wash. State Geol. Surv. Bull. 15, p. 69, pl. 9, fig. 76, 1912.

This variety was described by Weaver as follows:

Shell typically small, anterior margin slightly convex with a slope of 60°; posterior margin nearly straight with a slope of 45°; posterior surface of the shell undulatory because of broad groove extending from the beak to the margin. These characters are constant and do not seem to grade into the other varieties. Several hundred specimens from the same locality show these characteristics. The dimensions of the type are: length, 50 mm., height, 40 mm., convexity, 20 mm.

The hinge of this species as shown on the type and plesiotype is very heavy, the hinge plate very wide and thick; chondophore deep, roofed, but apparently not overhung by an accessory; the left cardinal is partially worn so its height is unknown; the arms are of equal length, extending ventrally nearly across the hinge plate; right cardinal not clearly shown in the specimens, the anterior arm was probably rather inconspicuous, posterior arm represented by a heavy basal ridge; laterals smooth, very robust, low; the anterior one extends for a short distance dorsal to the cardinal arm; laminae low, the dorsal ones formed entirely from the thickened dorsal margin of the shell and not represented by a distinct tooth. The hinge plate at the ventral ends of the laterals is sharply truncated.

The general shape is stated to be quite constant, especially as regards the posterior flexure. The hinge of the few specimens observed seem quite constant and sufficiently different from any other species or variety to deserve specific rank.

This species might be confused with *M. densata* or *M. alta*, but it is readily separable from either of these upon the basis of its unique type of dorsal laminae and its robust laterals.

The type of this species was obtained from Sylvia Creek, Chehalis County, Washington.

Occurrence.—Miocene: Upper Miocene of Sylvia Creek, Chehalis County, Washington (Weaver).

MULINIA LANDESI (Weaver)

Pseudocardium landesi Weaver, Wash. State Geol. Surv. Bull. 15, p. 69, pl. 9, fig. 75, 1912.

This species was described by Weaver as follows:

Shell thick, equivalve, nearly equilateral; anterior and posterior margins sloping steeply and at about the same angle; base evenly rounded; beaks prominent and pointing slightly forwards; escutcheon narrow but fairly well defined. Surface ornamented with heavy concentric lines of growth; hinge moderately heavy. The dimensions of the type are: length, 45 mm., height, 53 mm., convexity, 25 mm.

The writer has not seen the type of this species. It comes from the same collecting locality as did the species *M. undilifera* and it may represent but a ventricose form of that variety.

The type of this species was obtained from Sylvia Creek, Chehalis County, Washington.

Occurrence.—Miocene: Upper Miocene of Sylvia Creek, Chehalis County, Washington (Weaver).

MULINIA PABLOENSIS, n. sp.

Plate 34, figures 4a and 4b

Shell rather ventricose, nearly equilateral, umbones usually posterior to the middle of the shell; anterior dorsal edge nearly straight, excavated in front of the beaks; anterior extremity rounded to subtruncate; posterior dorsal edge slightly convex, extremity strongly truncated; some specimens show a posterior umbonal ridge, which is imperfectly seen in the type; base broadly arcuate. Surface roughened by numerous irregular lines of growth. Pallial sinus shallow;

other muscle scars deeply impressed. The hinge of the type lacks the posterior laminae and the posterior arm of the cardinal. Hinge plate rather heavy, chondophore relatively shallow, roofed; right cardinal with a small anterior arm which is closely appressed to the dorsal margin of the shell; anterior laminae long, strongly striated on their inner sides, the dorsal one being nearly as long as the ventral one, and arising as a long thin tooth, from the hinge plate to a height greater than that of the adjacent shell margin. In one specimen the ventral lamina is rather heavy and distinctly striated, not confluent with the anterior arm of the cardinal. The cotype shows the left valve with a rather small but prominent cardinal and large striated laterals, which are distant from the umbones, the anterior one not reaching to the cardinal arm. The dimensions of the type are: height, 43 mm., convexity, 18 mm. Those of the cotype are: length, 54 mm., height, 48 mm., convexity, 36 mm.

This species is extremely variable in general shape, paralleling in many respects the forms assumed by *Mulinia densata*. It differs from all mulinoid species of the Coast region in the striated character of its laterals and laminae.

The type was obtained at University of California Locality 1946, which was described by J. P. Buwalda in the following words: "About 150 feet slope distance up the south-west side of the highest hill north-east of Joe Mendosa's house, which is about one-half mile south-west of Shell Ridge, Concord Sheet, Contra Costa County, California."

Occurrence.—Miocene: Upper Monterey to Upper San Pablo. Found at a number of localities in the region of Mount Diablo, California.

GENERIC POSITION UNCERTAIN

MACTRA(?) GIBBSANA Meek

Maetra gibbsana Meek, Proc. Phila. Acad. Nat. Sci., vol. 13, p. 315, 1861; Bull. U. S. Geol. and Geog. Surv. Terr., vol. 2, no. 4, p. 374, pl. 2, figs. 8, 8a and 8b, 1876.

Meek described this species as follows:

Shell transversely oval, or subtrigonal, moderately convex, rather thin; anterior side narrowly rounded; base forming a regular semielliptical curve; posterior side slightly truncated at the immediate extremity, abruptly

rounded or subangular at its connection with the base below; dorsal outline sloping from the beaks in front and behind, at an angle of 120° ; beaks central, rather elevated, but small, and not projecting much above the hinge margin; surface marked only by moderately distinct lines of growth. Posterior muscular impression oval, well-defined; pallial line distinct, and provided with a rather deep, horizontal sinus, about one-third longer than wide. The type specimen had the following dimensions: length, 55 mm., height, 41 mm., convexity, 12 mm.

The type of this species was obtained from a piece of float found on the shore of the Straits of Juan de Fuca.

Occurrence.—Cretaceous (?); Straits of Juan de Fuca (Meek).

MACTRA(?) MONTEREYANA Arnold

Mactra montereyana Arnold, Proc. U. S. Nat. Mus., vol. 34, p. 381, pl. 35, fig. 2, 1908; U. S. Geol. Surv. folio 163, pl. 35, fig. 2, 1909.

Arnold described this species as follows:

Shell attaining a length of at least 30 mm.; width a little more than one-half length, subtrigonal, compressed, subequivalve, inequilateral; umbones a little behind middle, small, turned slightly forward; anterior margin considerably longer than posterior; very gently convex; anterior extremity quite sharply angulated below; a faintly developed carina or angle, most prominent near umbo, extends from the latter to the anterior extremity; base only very slightly rounded; posterior dorsal margin nearly straight, sloping only moderately steeply; posterior extremity regularly rounded and situated nearly midway between base and umbo; surface sculptured by numerous fine incremental lines and numerous obsolete short undulations. The dimensions of the type are: length, 31 mm., height, 18 mm., convexity, 2 mm.

This form has not been recognized by the writer. Its generic position is uncertain, but judging from the cut and the description, it is more likely to be a *Spisula* than a *Mactra*.

This species was described from a fossil specimen obtained from the Monterey shales on Love Creek, Santa Cruz County, California. The type is in the United States National Museum under catalogue number 165463.

Occurrence.—Miocene: Monterey group, Santa Cruz Mountains, California (Arnold).

MACTRA(?) STANTONI Arnold

Mactra stantoni Arnold, Proc. U. S. Nat. Mus., vol. 34, p. 357, pl. 31, fig. 3, 1908.

This species was described by Arnold as follows:

Shell averaging from 40 to 50 mm. in length, subtrigonal in outline, altitude about five-sevenths of length, equivalve, equilateral, the beaks located midway, the shell moderately thin, moderately convex. Anterior margin only very slightly depressed in front of beaks; quite evenly but somewhat acutely rounded in front; base evenly rounded; posterior extremity not quite as attenuated as anterior; a faint suggestion of an angle or carina extends from the beak to the posterior extremity. Surface sculptured by numerous small but sharply defined quite regular concentric ridges, separated by interspaces somewhat narrower than the latter, also by fine incremental lines which appear more prominent where the concentric ridges are obsolete. Hinge only moderately strong, umbonal pit small; lateral teeth high and thin, extending above the adjacent margins of the shell. Interior unknown. The dimensions of the type are: length, 50 mm., height, 34 mm., convexity, 12 mm.

This species has not been available for study, therefore its definite relationships are unknown.

The type of this species was obtained from the Chico series at Pigeon Point, San Mateo County, California. It was deposited in the United States National Museum under catalogue number 31001.

Occurrence.—Cretaceous: Chico series, Pigeon Point, San Mateo County, California (Arnold).

MACTRA(?) TENUISSIMA Gabb

Mactra tenuissima Gabb, Pal. Cal., vol. 2, p. 179, pl. 29, fig. 68, 1869.

Gabb described this species as follows:

Shell small, extremely thin, subequilateral; beaks central, small, pointed slightly in advance; anterior end obliquely and convexly subtruncated; base regularly convex. Surface marked by minute, concentric striae of growth; an angulated ridge runs from the umbones to the posterior basal angle. Pallial sinus deep and narrow. The dimensions of the type as given by Gabb are equivalent to: length, 27.9 mm., height, 19.3 mm., and convexity, 3.8 mm.

This form has been reported from the Martinez group of Lake County by Dickerson.²⁶ The specimens upon which his determinations are based do not reveal the generic characters of the form. It must therefore be listed as a questionable mactrine species.

Occurrence.—Eocene: Martinez group (Dickerson).

²⁶ Dickerson, R. E., Univ. Calif. Publ. Bull. Dept. Geol., vol. 8, p. 96, 1914.

SPISULA(?) WEAVERI Packard

Plate 27, figure 9

Spisula (?) weaveri Packard, Dickerson, Univ. Calif. Publ. Bull. Dept. Geol., vol. 8, p. 139, pl. 12, figs. 4a, 4b, 1914.

Packard described this species as follows:

Shell small, relatively thick, subtrigonal to oval, moderately ventricose, evenly rounded; umbones nearly central, prosogyrate, prominent, nearly adjacent; anterior dorsal margin concave for a distance equal to about one-third the height of the shell; anterior extremity slightly attenuated, evenly rounded; base broadly rounded, curving gently in the dorsal region to the beak; surface roughened by coarse lines of growth; hinge and interior but imperfectly known. The dimensions of the type are: length, 32 mm., height, 26 mm., convexity, 5 mm.

There is considerable variation in the outlines of this species. A specimen doubtfully compared to this species was noted in the collections of the Scripps Institution for Biological Research from the Tejon of Rose Cañon, San Diego County. It clearly shows the impressions of a spisuloid dentition.

The type was obtained from the Martinez near Stewartville, Contra Costa County, at University of California Locality 1556, which may be described as follows: NE $\frac{1}{4}$ of NW $\frac{1}{4}$ of Sec. 15, T 1 N, R 1 E, a little over one mile south of Stewartville, ten feet above the Martinez Chico contact.

Occurrence.—Eocene: Lower Martinez, Mount Diablo region, California.

SPECIES NOT VALID

MACTRA(?) GABIOTENSIS Conrad

Mactra(?) gabiottensis Conrad, Pac. R. R. Reports, vol. 7, p. 194, pl. 7, fig. 3, 1854-55.

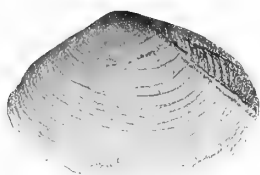
The description of this species was based upon a cast of a fossil specimen obtained from Gaviota Pass, California. Its general outline is comparable to several Miocene mactrine species and therefore it must be declared an invalid species.

EXPLANATION OF PLATE 12

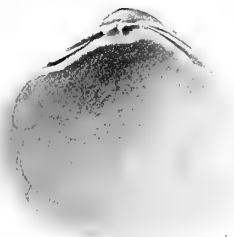
- Fig. 1a. *Macra stultora* Linnaeus. $\times 1$.
Interior of the left valve of the typical species of the genus
Macra. Foreign, Recent.
- Fig. 1b. *Macra stultora* Linnaeus. $\times 1$. Foreign, Recent.
- Fig. 2a. *Macra nasuta* Gould. $\times 1$. Recent.
- Fig. 2b. *Macra nasuta* Gould. $\times 1$. Recent.
- Fig. 2c. *Macra nasuta* Gould. $\times 1$. Recent.
- Fig. 3a. *Macra dolabriformis* (Conrad). $\times 2$. Recent.
- Fig. 3b. *Macra dolabriformis* (Gould). $\times 2$. Recent.
- Fig. 3c. *Macra dolabriformis* (Conrad). $\times 2$. Recent.
- Fig. 4a. *Macra exoleta* Gray. $\times 1$. Pleistocene.
- Fig. 4b. *Macra exoleta* Gray. $\times 1$. Pleistocene.



1a



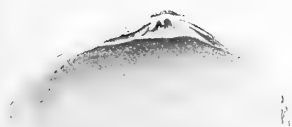
2a



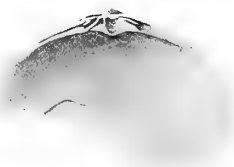
1b



2b



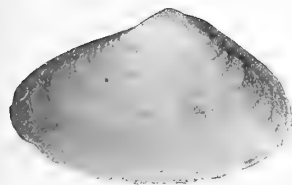
3a



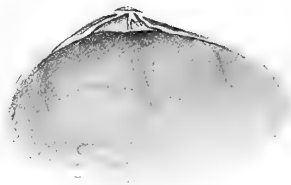
2c



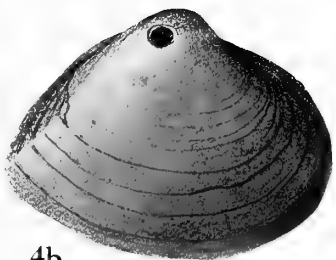
4a



3b



3c



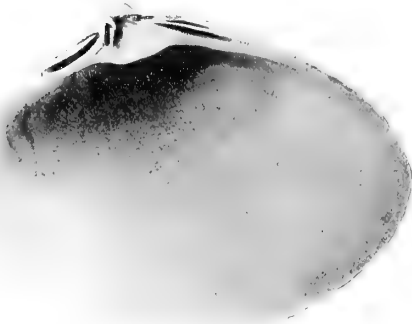
4b



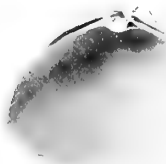
EXPLANATION OF PLATE 13

All figures natural size.

- Fig. 1a. *Spisula solidissima* Dillwyn. Atlantic Coast, Recent.
The type of the subgenus *Hemimacra*.
- Fig. 1b. *Spisula solidissima* Dillwyn. Atlantic Coast, Recent.
- Fig. 2. *Macra exoleta* Gray. Pleistocene.
- Fig. 3. *Macra trampasensis*, n. sp. Miocene.
" Umbonal view.
- Fig. 4. *Spisula voyi* (Gabb). Pliocene.
Probably Gabb's type.



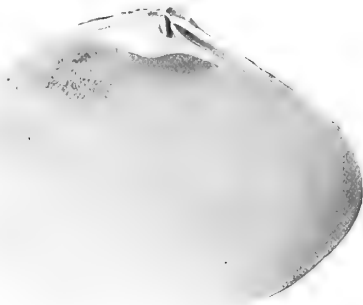
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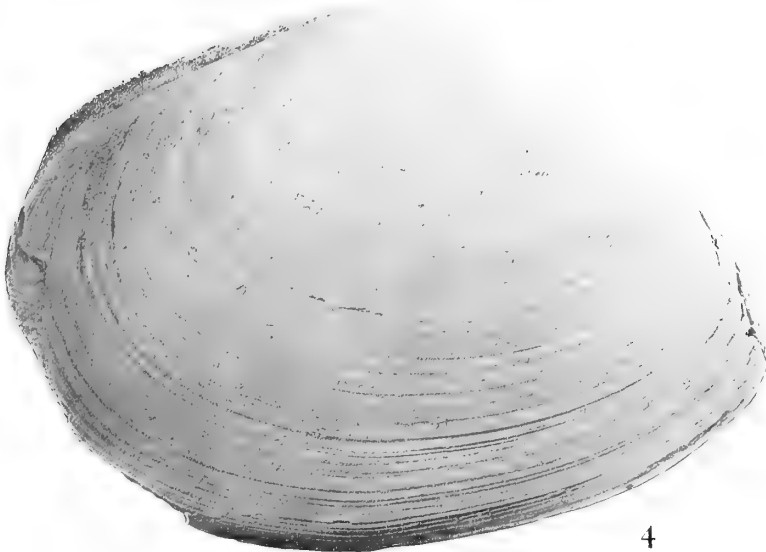
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3



1b



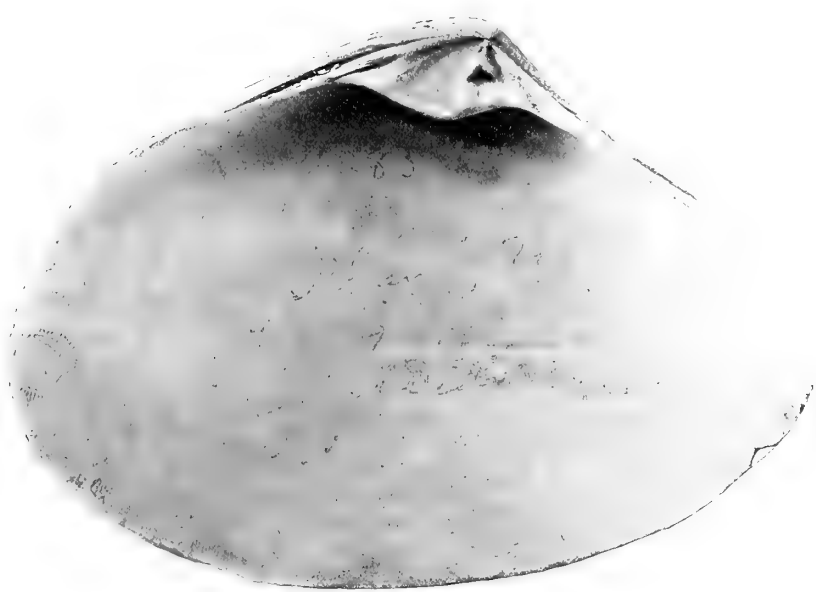
4

EXPLANATION OF PLATE 14

All figures natural size.

Fig. 1. *Spisula voyi* (Gabb). Recent.

Fig. 2. *Spisula voyi* (Gabb). Recent.



1



2

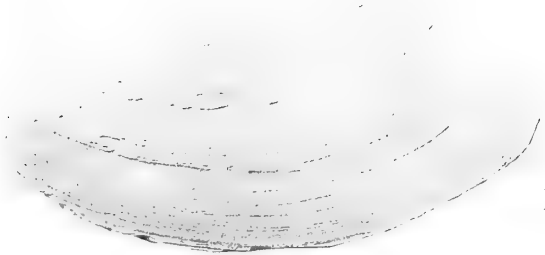
EXPLANATION OF PLATE 15

All figures natural size.

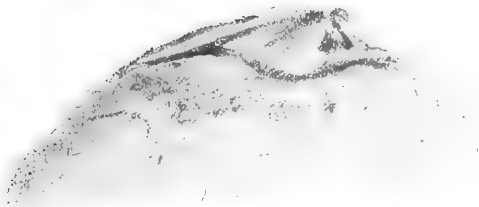
Fig. 1a. *Spisula voyi* (Gabb). Pliocene.

Fig. 1b. *Spisula voyi* (Gabb). Pliocene.

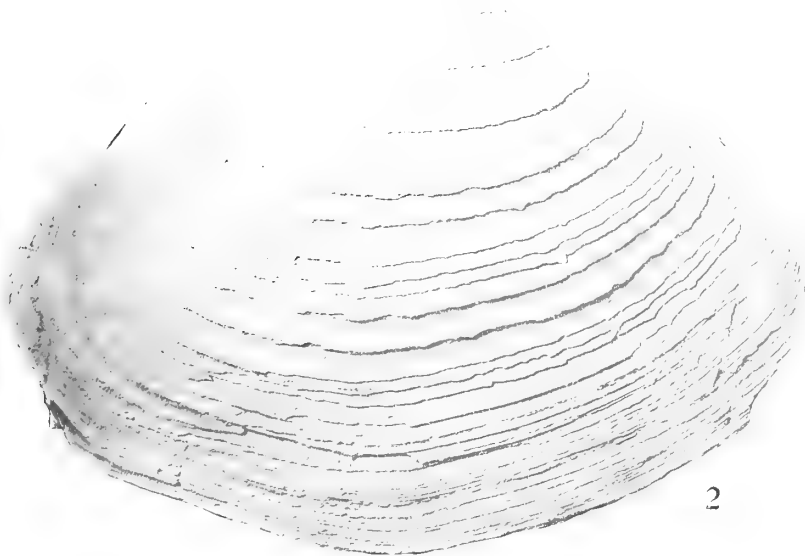
Fig. 2. *Spisula voyi* (Gabb). Pliocene.



1a



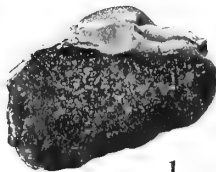
1b



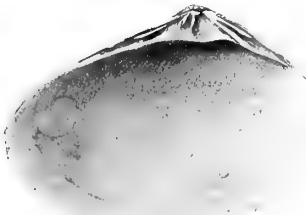
2

EXPLANATION OF PLATE 16

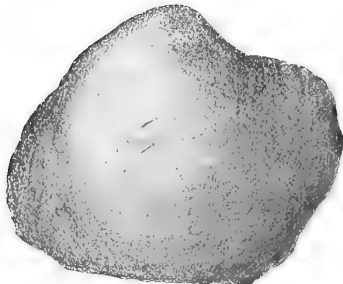
- Fig. 1. *Macra trampasensis*, n. sp. $\times 1\frac{1}{2}$. Miocene.
Fragment of left hinge, showing the cardinal.
- Fig. 2. *Macra trampasensis*, n. sp. $\times 1$. Miocene.
- Fig. 3a. *Spisula planulata* (Conrad). $\times 1$. Recent.
- Fig. 3b. *Spisula planulata* (Conrad). $\times 1$. Recent.
- Fig. 3c. *Spisula planulata* (Conrad). $\times 1$. Recent.
- Fig. 4a. *Macra californica* Conrad. $\times 2$. Recent.
- Fig. 4b. *Macra californica* Conrad. $\times 2$. Recent.
- Fig. 4c. *Macra californica* Conrad. $\times 2$. Recent.



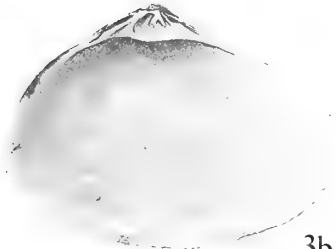
1



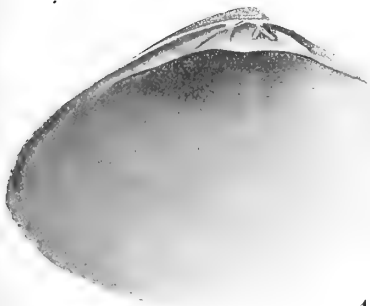
3a



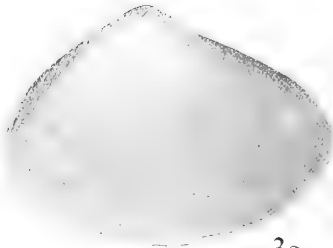
2



3b



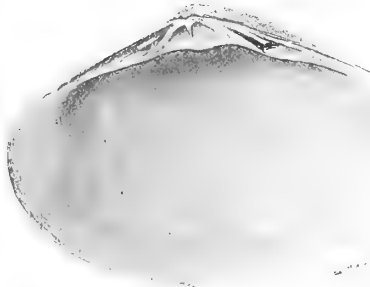
4a



3c



4b



4c

EXPLANATION OF PLATE 17

Natural size.

Spisula catilliformis Conrad. Recent.



EXPLANATION OF PLATE 18

Both figures natural size.

Fig. 1. *Spisula catilliformis* Conrad. Recent.
Left hinge of a young specimen.

Fig. 2. *Spisula catilliformis* Conrad. Recent.



1



2

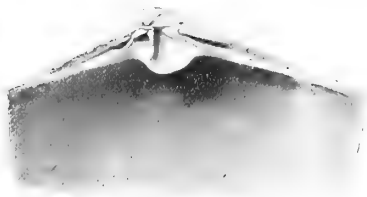
EXPLANATION OF PLATE 19

All figures natural size.

- Fig. 1a. *Spisula catilliformis* Conrad. Miocene.
Hinge of the left valve.
- Fig. 1b. *Spisula catilliformis* Conrad. Miocene.
- Fig. 2. *Spisula catilliformis* Conrad. Recent.
Right hinge of a young specimen.



1a



2



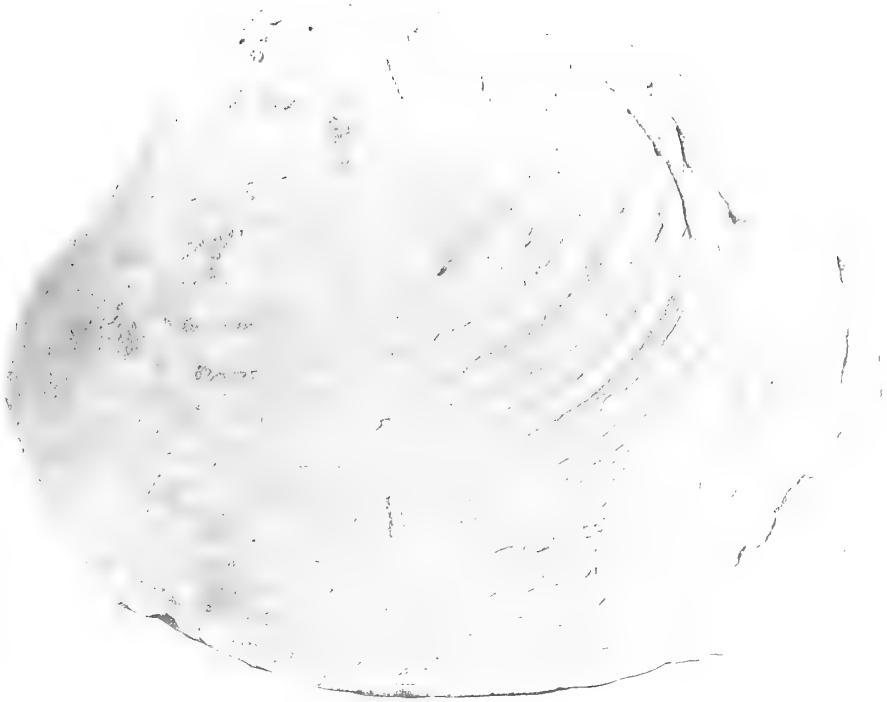
1b

EXPLANATION OF PLATE 20

Both figures natural size.

Fig. 1a. *Spisula mercedensis*, n. sp. Pliocene.

Fig. 1b. *Spisula mercedensis*, n. sp. Pliocene.
Left hinge of the type.



1a

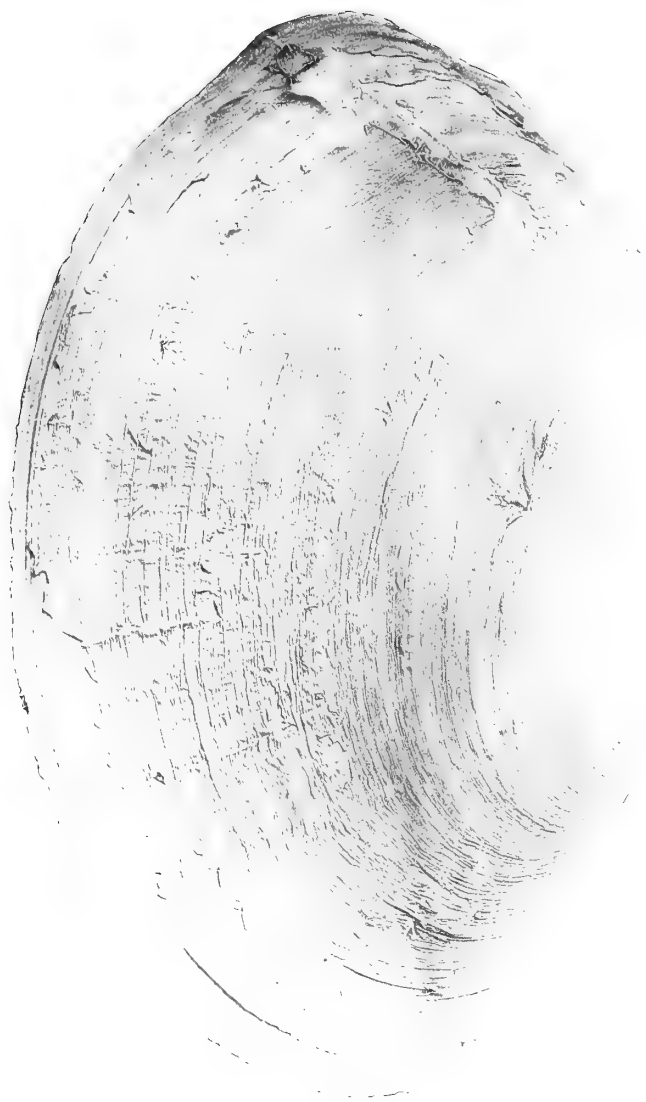


1b

EXPLANATION OF PLATE 21

Natural size.

Spisula hemphillii (Dall). Recent.



EXPLANATION OF PLATE 22

Natural size.

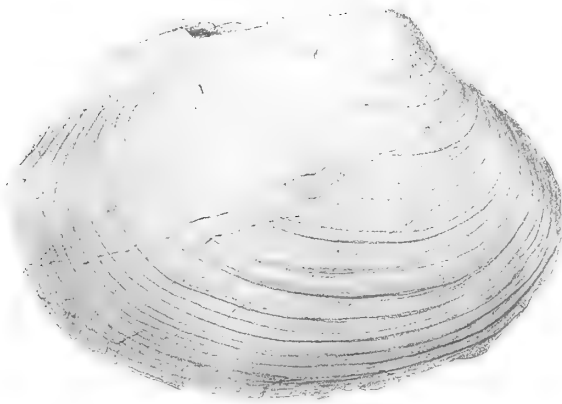
Spisula hemphillii (Dall). Recent.



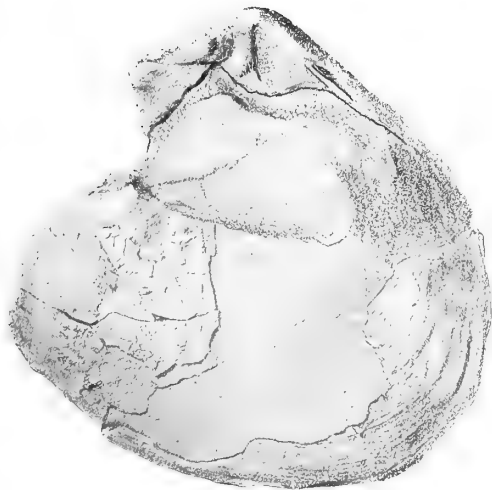
EXPLANATION OF PLATE 23

All figures natural size.

- Fig. 1. *Spisula occidentalis* (Gabb). Miocene.
Fig. 2. *Spisula occidentalis* (Gabb). Miocene.
Fig. 3. *Spisula occidentalis* (Gabb). Miocene.
Fig. 4. *Spisula abscissa* (Gabb). Miocene.
Left hinge.
Fig. 5. *Spisula albaria* (Conrad), var. *ramonensis*, n. var. Miocene.
Hinge of left valve of cotype.



1a



2



3



4



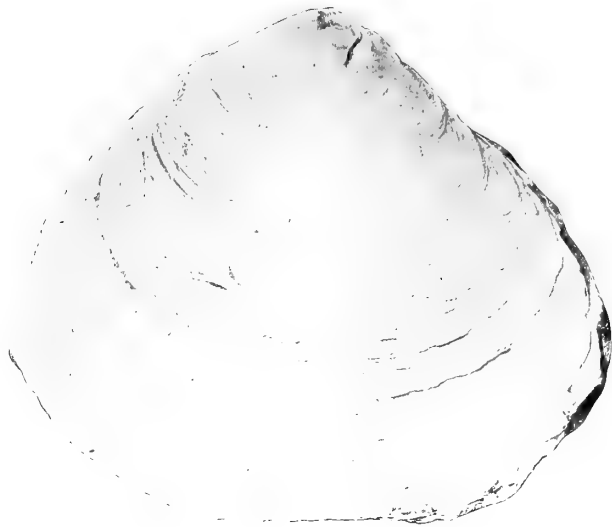
5

EXPLANATION OF PLATE 24

Both figures natural size.

Fig. 1. *Spisula albaria* (Conrad). Miocene.

Fig. 2. *Spisula abscissa* (Gabb). Miocene.



1



2

EXPLANATION OF PLATE 25

All figures natural size.

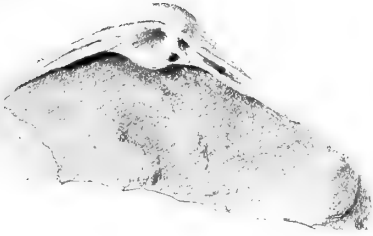
- Fig. 1. *Spisula albaria* (Conrad) var. *ramonensis*, n. var. Miocene.
Hinge of type.
- Fig. 2. *Spisula albaria* (Conrad) var. *ramonensis*, n. var. Miocene.
- Fig. 3. *Spisula albaria* (Conrad). Pliocene.
Fragment of left hinge.
- Fig. 4. *Spisula albaria* (Conrad). Pliocene.
Showing the right cardinal.
- Fig. 5. *Spisula albaria* (Conrad). Pliocene.
- Fig. 6. *Spisula albaria* (Conrad). Pliocene.
- Fig. 7. *Spisula albaria* (Conrad). Pliocene.
- Fig. 8. *Spisula albaria* (Conrad). Miocene.



3



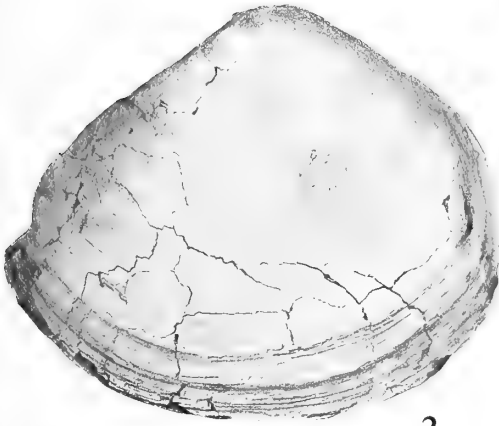
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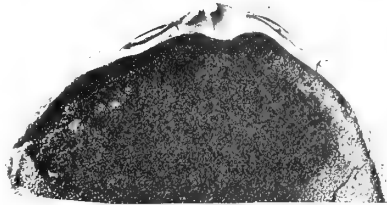
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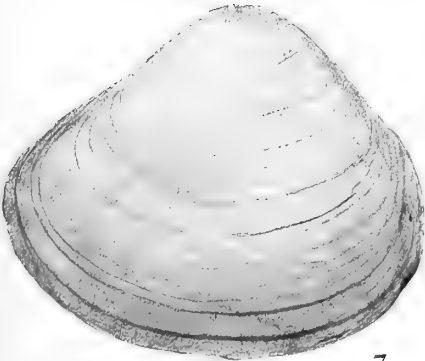
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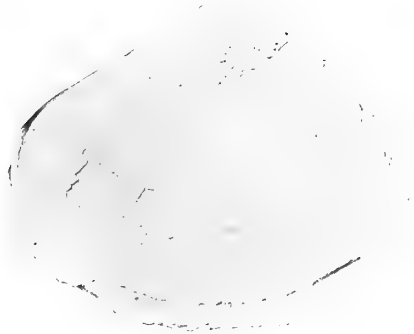
2



6



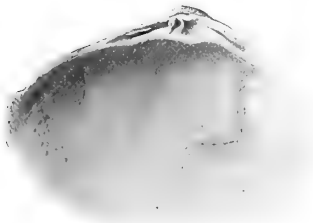
7



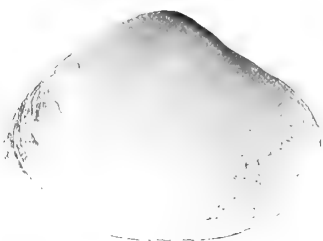
8

EXPLANATION OF PLATE 26

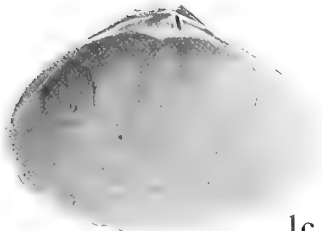
- Fig. 1a. *Spisula falcata* (Gould). $\times 1$. Recent.
Fig. 1b. *Spisula falcata* (Gould). $\times 1$. Recent.
Fig. 1c. *Spisula falcata* (Gould). $\times 1$. Recent.
Fig. 2a. *Spisula selbyensis*, n. sp. $\times 2$. Miocene.
Right hinge.
Fig. 2b. *Spisula selbyensis*, n. sp. $\times 1$. Miocene.
Fig. 3. *Spisula selbyensis*, n. sp. $\times 2$. Miocene.
Fig. 4. *Spisula ashburnerii* (Gabb). $\times 3$ (?). Cretaceous.
Hinge of right valve. (After Gabb).
Fig. 5. *Spisula ashburnerii* (Gabb). $\times 3$ (?). Cretaceous.
Hinge of left valve. (After Gabb).



1a



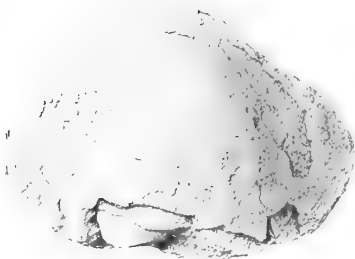
1b



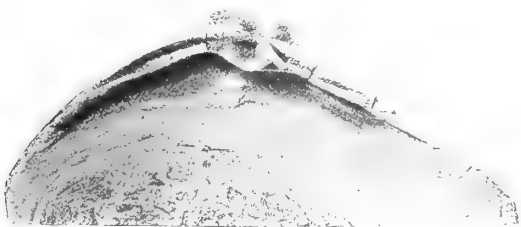
1c



2a



2b



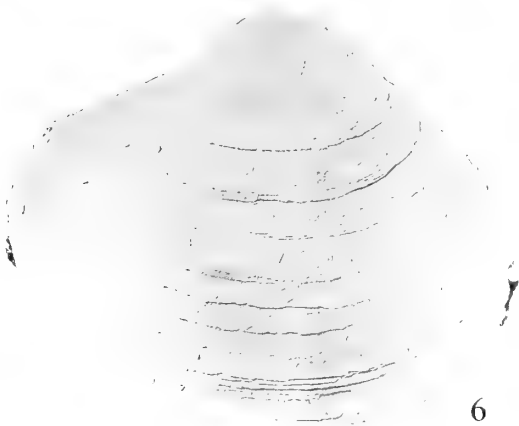
3



4



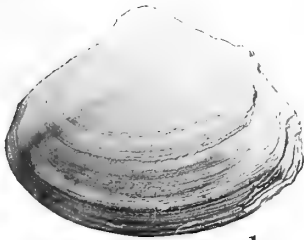
5



6

EXPLANATION OF PLATE 27

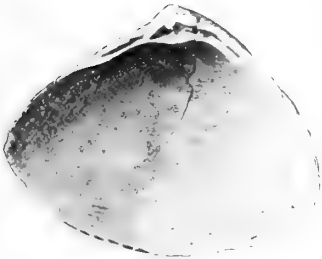
- Fig. 1. *Spisula ashburnerii* (Gabb). × 2. Cretaceous.
- Fig. 2. *Spisula gabbiana* (F. M. Anderson). × 1. Cretaceous.
Exterior of the type. (After Anderson).
- Fig. 3. *Spisula merriami*, n. sp. × 2. Eocene.
- Fig. 4. *Spisula merriami*, n. sp. × 2. Eocene.
- Fig. 5. *Spisula tejonensis*, n. sp. × 2. Eocene.
- Fig. 6. *Spisula chicoensis*, n. name. × 1. Cretaceous.
- Fig. 7. *Spisula chicoensis*, n. name. × 1. Cretaceous.
Hinge of left valve.
- Fig. 8. *Spisula coalingensis* (Arnold). × 1. Pliocene.
- Fig. 9. *Spisula* (?) *weaveri* Packard. × 1. Eocene.



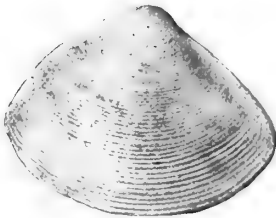
1



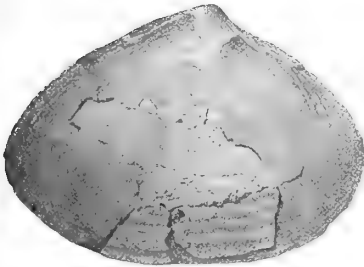
2



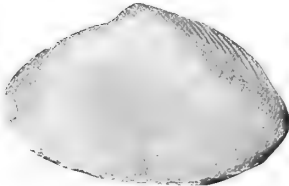
3



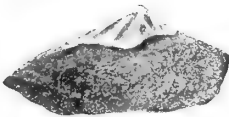
4



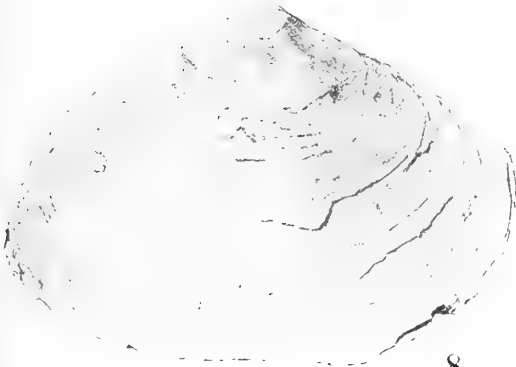
6



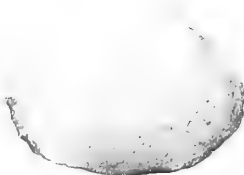
5



7



8



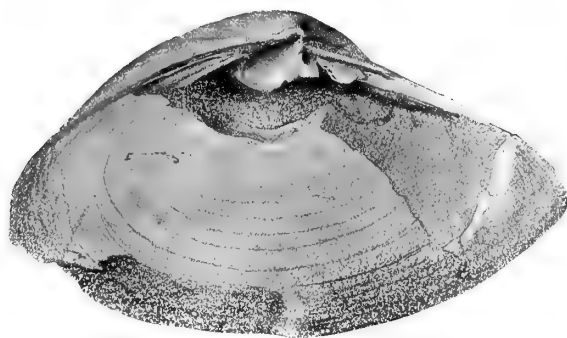
9



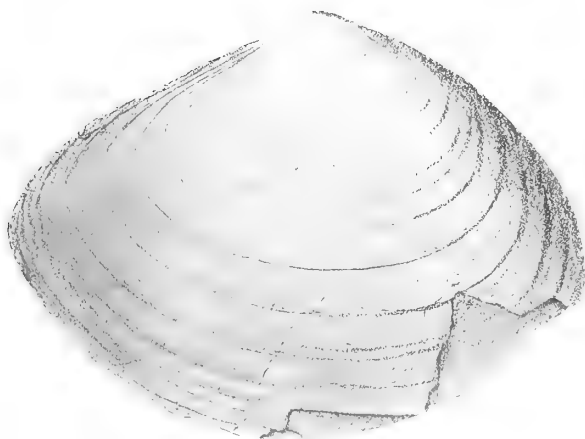
EXPLANATION OF PLATE 28

All figures natural size.

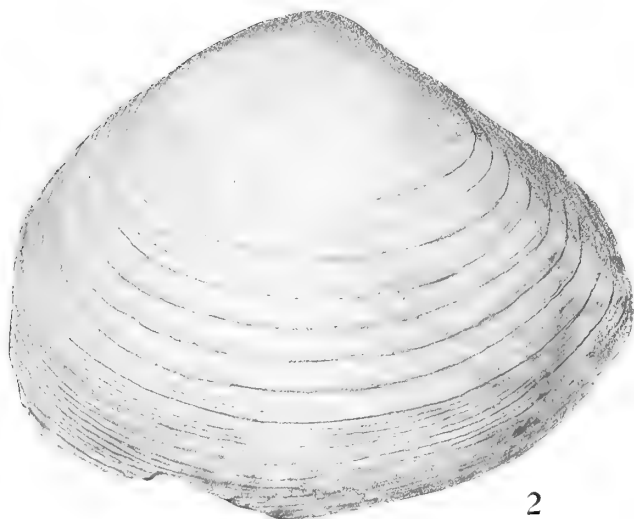
- Fig. 1a. *Spisula brevirostrata*, n. sp. Pliocene.
Hinge of the type specimen.
- Fig. 1b. *Spisula brevirostrata*, n. sp. Pliocene.
Exterior of the type specimen.
- Fig. 2. *Spisula brevirostrata*, n. sp. Pliocene.



1a



1b

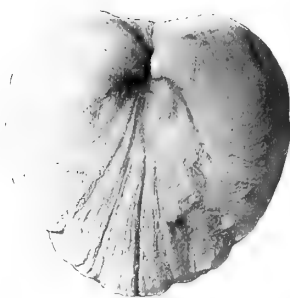


2

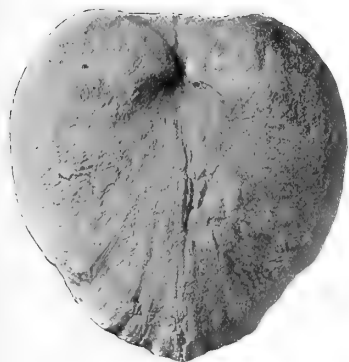
EXPLANATION OF PLATE 29

All figures natural size.

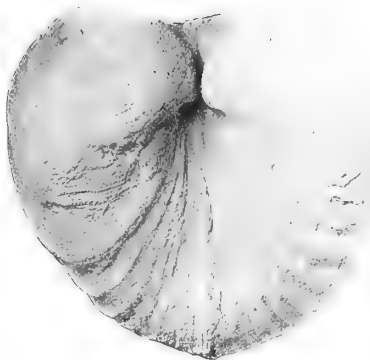
- Fig. 1. *Mulinia densata* Conrad. San Pablo, Miocene.
Fig. 2. *Mulinia densata* Conrad. San Pablo, Miocene.
Fig. 3. *Mulinia densata* Conrad. San Pablo, Miocene.
Note type of umbones as compared with the figures above.



1



2



3



4

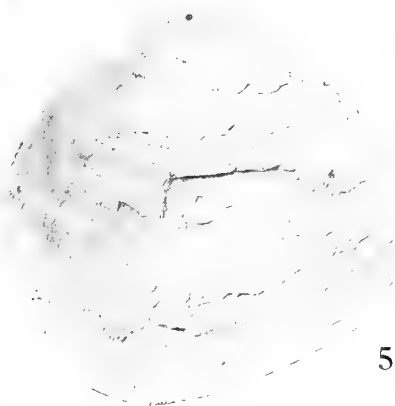
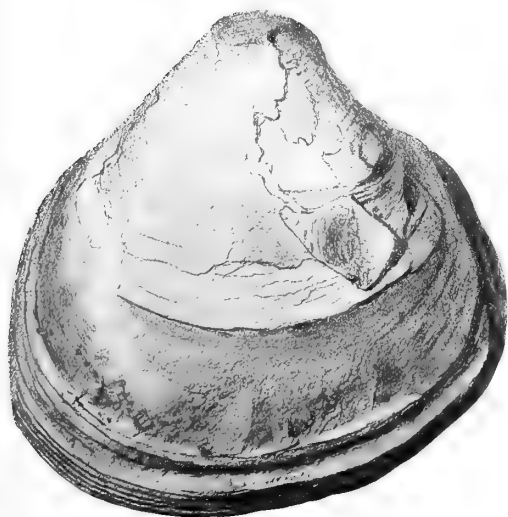
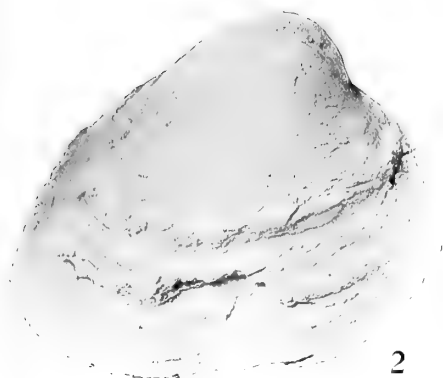
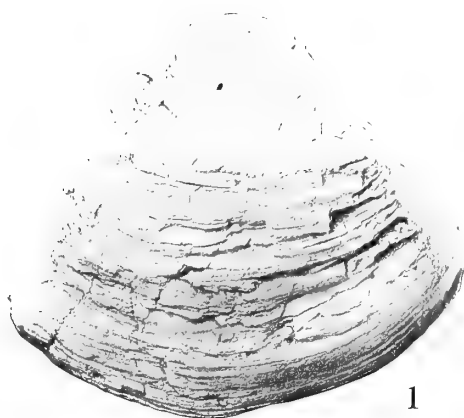


EXPLANATION OF PLATE 30

All figures natural size.

Mulinia densata Conrad. San Pablo, Miocene.

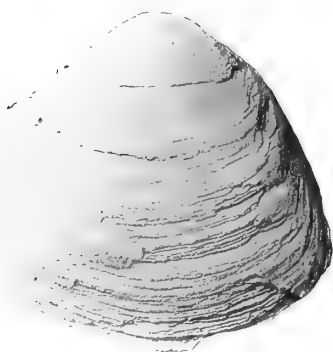
Note the variation in shape in these specimens from the same
collecting locality.



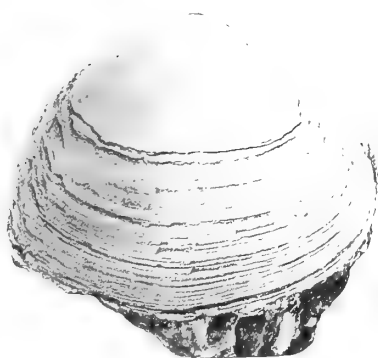
EXPLANATION OF PLATE 31

All figures natural size.

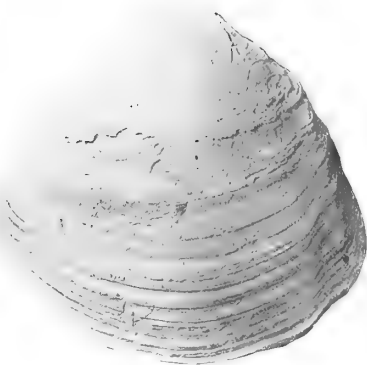
- Fig. 1. *Mulinia densata* Conrad. Etchegoin, Pliocene.
Fig. 2. *Mulinia densata* Conrad. Etchegoin, Pliocene.
Fig. 3. *Mulinia densata* Conrad. San Pablo, Miocene.
Fig. 4. *Mulinia densata* Conrad. Etchegoin, Pliocene.
Fig. 5. *Mulinia densata* Conrad. Etchegoin, Pliocene.
Fig. 6. *Mulinia densata* Conrad. Etchegoin, Pliocene.



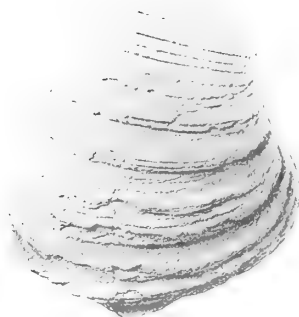
1



2



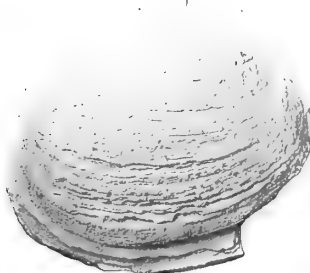
3



4



5



6

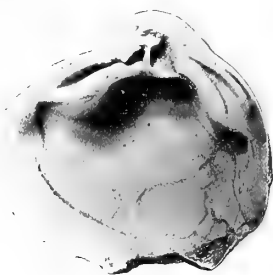
EXPLANATION OF PLATE 32

All figures natural size.

- Fig. 1. *Mulinia densata* Conrad. Etchegoin, Pliocene.
Fig. 2. *Mulinia densata* Conrad. San Pablo, Miocene.
Fig. 3. *Mulinia densata* Conrad. Etchegoin, Pliocene.
Fig. 4. *Mulinia densata* Conrad. San Pablo, Miocene.
Fig. 5. *Mulinia densata* Conrad. Etchegoin, Pliocene.
Fig. 6. *Mulinia densata* Conrad. Etchegoin, Pliocene.



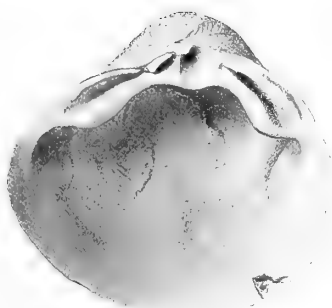
1



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3



4



5

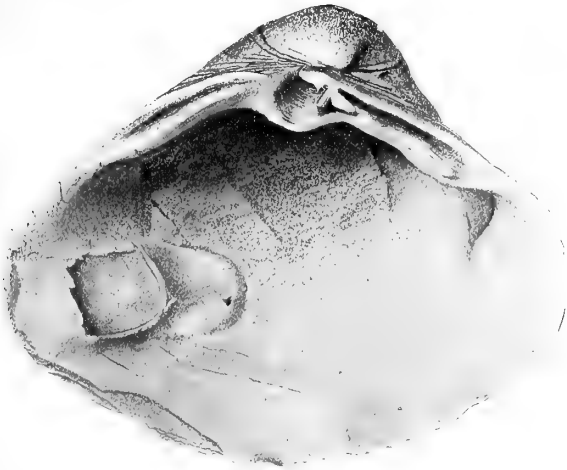


6

EXPLANATION OF PLATE 33

All figures natural size.

- Fig. 1. *Mulinia densata* Conrad. Etchegoin, Pliocene.
Fig. 2. *Mulinia densata* Conrad. San Pablo, Miocene.
Fig. 3. *Mulinia densata* Conrad. Etchegoin, Pliocene.
Fig. 4. *Mulinia densata* Conrad. Etchegoin, Pliocene.
Fig. 5. *Mulinia densata* Conrad. Etchegoin, Pliocene.



1



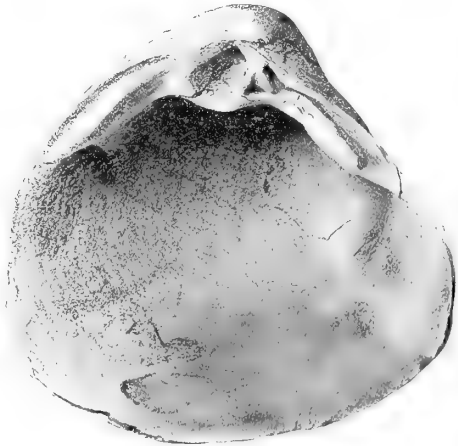
2



3



4



5

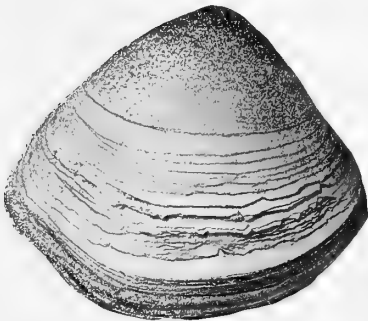
EXPLANATION OF PLATE 34

All figures natural size.

- Fig. 1a. *Mulinia undilifera* (Weaver). Miocene.
Hinge of the type specimen.
- Fig. 1b. *Mulinia undilifera* (Weaver). Miocene.
Exterior of the type specimen.
- Fig. 2. *Mulinia undilifera* (Weaver). Miocene.
- Fig. 3. *Mulinia undilifera* (Weaver). Miocene.
- Fig. 4a. *Mulinia pabloensis*, n. sp. Miocene.
- Fig. 4b. *Mulinia pabloensis*, n. sp. Miocene.



1



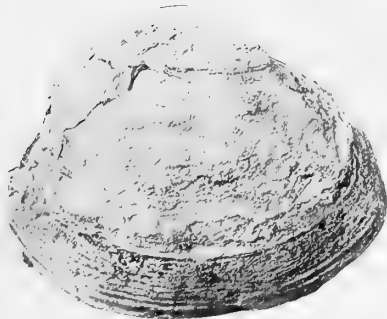
2



3



4



5



6

EXPLANATION OF PLATE 35

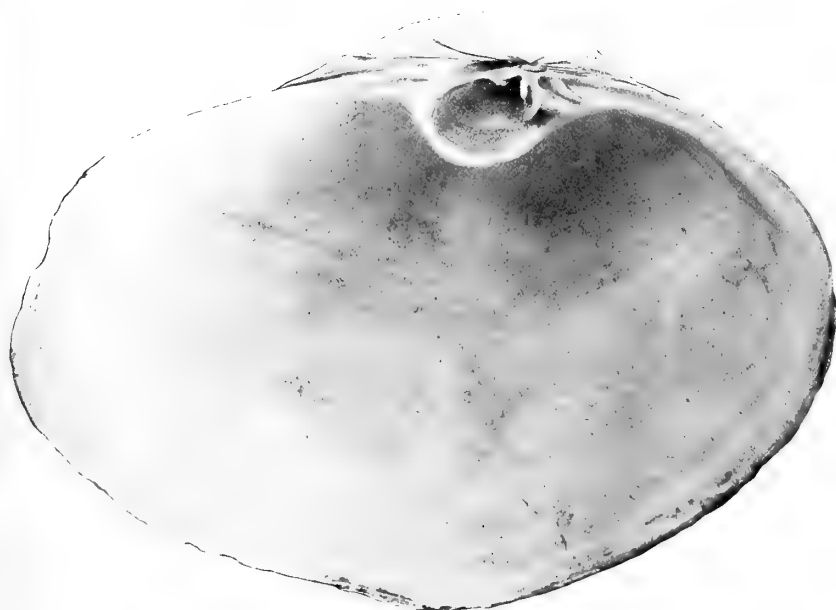
Both figures natural size.

Fig. 1*a*. *Schizothaerus nuttallii* (Conrad). Recent.

Fig. 1*b*. *Schizothaerus nuttallii* (Conrad). Recent.



1a



1b

VOLUME 7—(Continued).

6. Physiography and Structure of the Western El Paso Range and the Southern Sierra Nevada, by Charles Laurence Baker.....	50c
7. Fauna from the Type Locality of the Monterey Series in California, by Bruce Martin.....	10c
8. Pleistocene Rodents of California, by Louise Kellogg.....	15c
9. Tapir Remains from Late Cenozoic Beds of the Pacific Coast Region, by John C. Merriam.....	10c
10. The Monterey Series in California, by George Davis Loubderback.....	65c
11. Supplementary Notes on Fossil Sharks, by David Starr Jordan and Carl Hugh Beal.....	10c
12. Fauna of the Eocene at Marysville Buttes, California, by Roy E. Dickerson.....	45c
13. Notes on <i>Scutella norrisi</i> and <i>Scutaster andersoni</i> , by Robert W. Pack.....	5c
14. The Skull and Dentition of a Camel from the Pleistocene of Rancho La Brea, by John C. Merriam.....	20c
15. The Petrographic Designation of Alluvial Fan Formations, by Andrew C. Lawson.....	10c
16. A Peculiar Horn or Antler from the Mohave Miocene of California, by John C. Merriam.....	5c
17. <i>Nothrotherium</i> and <i>Megalonyx</i> from the Pleistocene of Southern California, by Chester Stock.....	15c
18. Notes on the Canid Genus <i>Tephrocyon</i> , by John C. Merriam.....	15c
19. Vertebrate Fauna of the Orindan and Siestan Beds in Middle California, by John C. Merriam.....	10c
20. Recent Observations on the Mode of Accumulation of the Pleistocene Bone Deposits of Rancho La Brea, by Reginald C. Stoner.....	10c
21. Preliminary Report on the Horses of Rancho La Brea, by John C. Merriam.....	20c
22. New Anchitheriine Horses from the Tertiary of the Great Basin Area, by John C. Merriam.....	15c
23. New Protelippine Horses from Tertiary Beds on the Western Border of the Mohave Desert, by John C. Merriam.....	5c
24. Pleistocene Beds at Manix in the Eastern Mohave Desert Region, by John P. Buwalda.....	25c
25. The Problem of Aquatic Adaptation in the Carnivora, as Illustrated in the Osteology and Evolution of the Sea-Otter, by Walter P. Taylor.....	30c

VOLUME 8.

1. Is the Boulder "Batholith" a Laccolith? A Problem in Ore-Genesis, by Andrew C. Lawson.....	25c
2. Note on the Faunal Zones of the Tejon Group, by Roy E. Dickerson.....	10c
3. Teeth of a Cestracient Shark from the Upper Triassic of Northern California, by Harold C. Bryant.....	5c
4. Bird Remains from the Pleistocene of San Pedro, California, by Loye Holmes Miller.....	10c
5. Tertiary Echinoids of the Carrizo Creek Region in the Colorado Desert, by William S. W. Kew.....	20c
6. Fauna of the Martinez Eocene of California, by Roy Ernest Dickerson.....	\$1.25
7. Descriptions of New Species of Fossil Mollusca from the Later Marine Neocene of California, by Bruce Martin.....	20c
8. The Fernando Group near Newhall, California, by Walter A. English.....	15c
9. Ore Deposition in and near Intrusive Rocks by Meteoric Waters, by Andrew C. Lawson.....	20c
10. The Agasoma-like Gastropods of the California Tertiary, by Walter A. English.....	15c
11. The Martinez and Tejon Eocene and Associated Formations of the Santa Ana Mountains, by Roy E. Dickerson.....	20c
12. The Occurrence of Tertiary Mammalian Remains in Northeastern Nevada, by John C. Merriam.....	10c
13. Remains of Land Mammals from Marine Tertiary Beds in the Tejon Hills, California, by John C. Merriam.....	5c
14. The Martinez Eocene and Associated Formations at Rock Creek on the Western Border of the Mohave Desert Area, by Roy E. Dickerson.....	10c
15. New Molluscan Species from the Martinez Eocene of Southern California, by Roy E. Dickerson.....	5c
16. A Proboscidean Tooth from the Truckee Beds of Western Nevada, by John P. Buwalda.....	5c
17. Notes on the Copper Ores at Ely, Nevada, by Alfred R. Whitman.....	10c
18. Skull and Dentition of the <i>Mylodont</i> Sloths of Rancho La Brea, by Chester Stock.....	15c
19. Tertiary Mammal Beds of Stewart and Ione Valleys in West-Central Nevada, by John P. Buwalda.....	30c
20. Tertiary Echinoids from the San Pablo Group of Middle California, by William S. W. Kew.....	10c
21. An Occurrence of Mammalian Remains in a Pleistocene Lake Deposit at Astor Pass, near Pyramid Lake, Nevada, by John C. Merriam.....	10c
22. The Fauna of the San Pablo Group of Middle California, by Bruce L. Clark.....	1.75

VOLUME 9.

1. New Series of the Hipparion Group from the Pacific Coast and Great Basin Provinces of North America, by John C. Merriam.....	10c
2. The Occurrence of Oligocene in the Contra Costa Hills of Middle California, by Bruce L. Clark	10c
3. The Epigene Profiles of the Desert, by Andrew C. Lawson.....	25c
4. New Horses from the Miocene and Pliocene of California, by John C. Merriam...	10c
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STRATIGRAPHY AND FAUNA OF THE TEJON EOCENE OF CALIFORNIA

BY

ROY E. DICKERSON

UNIVERSITY OF CALIFORNIA PRESS
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INTRODUCTION

Since Conrad first recognized *Cardita planicosta*, "the finger-post of the Eocene", with thirteen other species in a small boulder sent him by Blake, from the Cañada de las Uvas, the question of the occurrence of the Eocene, and later its relations, have from time to time excited interest and, in the time of Gabb, even acute controversy among the Pacific Coast geologists. The occurrence of great thicknesses of Eocene strata in the region north of Coalinga, Fresno County, California, has recently attracted the attention of various geologists engaged in oil work to the consideration of the divisions of

the Eocene of this coast. The stratigraphy and fauna of the Tejon is far better known than that of the Martinez. This is due to the somewhat greater distribution of the Tejon, its more abundant and better preserved fauna and to a well-marked constancy in certain phases of its lithology over all California. Stratigraphy alone is powerless in many cases to settle the structural features, as unconformable contacts with marked differences of dip and strike are generally cloaked; again, that many times there is only a disconformity between two formations very different in age is a common experience of the field geologist working in California. Lithology is very helpful at times, but great danger arises when correlation or even extended mapping is based upon this alone. Every device must be used in our efforts to solve the intricate questions arising in connection with the sedimentary formations, and among these, the careful determination of fossils and study of the related faunas is not the least. Here, as elsewhere, mistakes occur and to avoid them a thorough study of the faunas of the various groups is necessary. This paper will attempt to aid the geologist and palaeontologist to separate sharply the Tejon from the Martinez by describing the faunal differences as well as the lithological and structural ones.

The Tejon group is a unit both stratigraphically and faunally. Minor stratigraphic breaks may occur at various horizons within the group, but when these are evaluated by faunal studies they have been found to be of minor importance in all cases. From the lowermost horizon to the uppermost the faunas do not appear to be separated sharply, and many species range throughout the entire thickness of the Tejon. Very gradual changes in faunas, however, do occur and the writer recognizes four faunal zones in the Tejon group of California. These zones are, in ascending order, the *Turbinolia* zone, the *Rimella simplex* zone, the *Balanophyllia variabilis* zone, and the *Siphonalia sutterensis* zone. Of these the first three are present in the San Francisco Bay region. The uppermost is typically exposed in the Marysville Buttes, which are located in the center of the Sacramento Valley, and at several places along the eastern border of the Great Valley, on the western flanks of the Sierra Nevada. This zone may also be present in the Coalinga region. Its absence in the Mount Diablo section is probably due to post-Tejon and pre-Oligocene erosion, as there is a strong suggestion of unconformity between the Oligocene, the *Agasoma gravidum* zone and the Tejon at Walnut Creek. The Tejon is found in general to rest with distinct

unconformity upon the rocks of the underlying formations, but stratigraphic relations to the overlying formations are not always so clear. The Oligocene as represented by the *Agasoma gravidum* zone does not always appear to be sharply set off from the Tejon. Recent studies in the southern end of the Great Valley made by Clark Gester at San Emigdio and John Ruckman at Coalinga appear to show intergradation between the two groups. Faunally, however, the Tejon is distinct from both the Martinez Eocene below and the *Agasoma gravidum* zone (Oligocene) above.

The Ione formation of the Sierra Nevada foothill region is the uppermost member of the Tejon group and, as will be shown later, is the marine equivalent of a great portion of the Superjacent series, the land and stream-laid deposits of the Sierra Nevada.

ACKNOWLEDGMENTS

The writer is indebted to Mr. J. A. Taff and to Mr. G. C. Gester of the Southern Pacific Company for the facilities of their camp on Salt Creek and for their guidance in the field to the best collecting localities. It was the intention of Mr. Gester and the writer to describe the Cantua region in a joint paper, but this was prevented by Mr. Gester's departure for Peru. The faunal relations are so important that it was thought best to publish these results now and the complete stratigraphic discussion later.

The Tejon collections made by the December, 1913, field party of the Department of Palaeontology of the University of California were turned over to the writer by Dr. B. L. Clark and Mr. John Ruckman. The writer is especially indebted to Professor J. C. Merriam for the opportunity to make this investigation and for his kind criticism during its progress.

The writer has been assisted in this work by many persons. Professor J. C. Merriam, Dr. B. L. Clark, Dr. J. P. Buwalda, Dr. E. L. Packard, Mr. W. S. W. Kew, Mr. J. Ruckman, Mr. W. Gordon and other members of the 1911 and 1912 Summer School classes in Palaeontology rendered much help in the work in the Mount Diablo region.

REVIEW OF THE LITERATURE

The literature of the Tejon group is so voluminous that only the principal papers will be reviewed. These papers deal with age, fauna;

correlation, distribution and stratigraphy of the upper Eocene of California.

The first recognition of Eocene on the Pacific Coast was made by Conrad,¹ and was based upon the fossils contained in a boulder sent by Blake from Cañada de las Uvas.

Conrad described the following new species: *Cardium linteum*, *Dosinia alta*, *Meretrix uvasana*, *Meretrix californiana*, *Crassatella uvasana*, *Mytilus humerus*, *Volutilithes californica*, *Busycon(?) blakei* = (*Perissolax blakei*), *Clavatula(?) californica* = (*Fusinus californicus*), *Natica alveata* = (*Amauropsis alveata*), and he identified *Venericardia planicosta*, *Natica aetites(?)*, *Natica gibbosa* and *Crassatella alta* of the Claiborne Eocene.

Gabb² in 1864 described many species which Captain Horn collected from the vicinity of Cañada de las Uvas and referred the strata yielding this fauna to Division B of the Cretaceous. Whitney³ in the next volume described the type locality of the Tejon-Eocene as follows:

The Tejon group . . . the division B of Palaeontology, vol. 1, is peculiar to California. It is found most extensively developed in the vicinity of Fort Tejon and about Martinez. From the latter locality it forms an almost continuous belt in the Coast Ranges to Marshs', 15 miles east of Mount Diablo, where it sinks under the San Joaquin plain. It was also discovered by the different members of the survey at various points on the eastern face of the same range as far south as New Idria, and in the summer of 1866 by Mr. Gabb in Mendocino County, near Round Valley, the latter locality being the most northern point at which it is as yet known. . . .

This group contains a large and highly characteristic series of fossils, the larger part peculiar to itself, while a considerable percentage is found extending below into the next group (Martinez).

For several years the controversy concerning the age of the

¹ Pacific Railroad Reports, App. to Prelim. Geol. Rept. of W. P. Blake, Palaeontology, pp. 5-20, 1855. Reprinted in Pacific Railroad Reports, vol. 5, part 2, pp. 317-329, 1857.

² Gabb, Wm., Geological Survey of California, Palaeontology, vol. 1, 1864.

³ Whitney, J. D., Geological Survey of California, Palaeontology, vol. 2, p. 19 of preface, 1869.

⁴ Conrad, T. A., Observations on Certain Eocene Fossils described as Cretaceous, by W. M. Gabb in his Report published in Palaeontology of California, Am. Jour. Conchol., vol. 1, pp. 362-365, 1865; Further Observations on Mr. Gabb's Palaeontology of California, Am. Jour. Conchol., vol. 2, pp. 97-100, 1866; Check list of Invertebrate Fossils of North America, Eocene and Oligocene, p. 37, Smithsonian Misc. Coll. No. 200, 1866; Am. Jour. Sci., 2nd series, vol. 44, pp. 376-377, 1867.

⁵ Gabb, W. M., Reply to Mr. Conrad's Criticism on Mr. Gabb's Report on the Palaeontology of California, Am. Jour. Conchol. vol. 2, pp. 87-92, 1866; Amer. Jour. Sci., 2nd series, vol. 44, pp. 226-229, 1867; On the Subdivisions of the Cretaceous Formation in California, Cal. Acad. Sci. Proc., 1st series, vol. 3, pp. 301-306, 1867; Geol. Surv. California, Palaeontology, vol. 2, 1869.

Tejon was waged. Conrad,⁴ Gabb,⁵ Whitney,⁶ Cooper,⁷ Marcou,⁸ Heilprin,⁹ Newberry,¹⁰ White,¹¹ Becker,¹² Clark,¹³ Harris,¹⁴ Diller,¹⁵ all contributed to this question. The Cretaceous ghost of the Tejon was finally laid by Stanton¹⁶ and Merriam.¹⁷ Most of the papers cited deal with the Tejon in general, and direct references to the type locality are few in number.

The reader is referred to the papers by Clark and Stanton for a more complete review of the literature concerning the age and correlation of the Tejon.

Anderson¹⁸ mapped an area in the southern end of the San Joaquin Valley which included the type locality of the Tejon group and he described the stratigraphic relations there.

Watts,¹⁹ Cooper,²⁰ Lindgren and Turner²¹ described the stratigraphy and fauna of the Tejon of the Marysville Buttes

⁶ Whitney, J. D., *Geol. Surv. California, Palaeontology*, vol. 2, 1869.

⁷ Cooper, J. G., *The Eocene Epoch in California—Are there really no Eocene Strata?*, *Cal. Acad. Sci. Proc.*, 1st series, vol. 5, pp. 419-421, 1874.

⁸ Marcou, J., *Ann. Rept. Geol. Surv. West 100° Merid.*, pp. 167-169, 1876; *Note sur la géologie de la Californie*; *Bull. Soc. géol. France*, 3rd series, vol. 11, pp. 407-435, 1883.

⁹ Heilprin, A., *On the Occurrence of Ammonites in Deposits of Tertiary Age*, *Proc. Acad. Nat. Sci. Phila.*, vol. 34, p. 94, 1882; *On the Age of the Tejon Rocks of California, and the Occurrence of Ammonitic Remains in Tertiary Deposits*, *Proc. Acad. Nat. Sci., Phila.*, vol. 34, pp. 196-214, 1882.

¹⁰ Newberry, J. S., *On Supposed Tertiary Ammonites*, *Proc. Acad. Nat. Sci., Phila.*, vol. 34, pp. 194-195, 1882.

¹¹ White, C. A., *On Marine Eocene, Fresh-Water Miocene and other fossil Mollusca of Western North America*, *Bull. 18, U. S. Geol. Surv.*, pp. 7-9, 1885.

¹² Becker, G. F., *Notes on the Stratigraphy of California*, *Bull. 19, U. S. Geol. Surv.*, pp. 1-25, 1885.

¹³ Clark, Wm., *Correlation Essays, Eocene*, *Bull. 83, U. S. Geol. Surv.*, pp. 95-110, 1891.

¹⁴ Harris, G. D., *Correlation of the Tejon with Eocene Stages of the Gulf Slope*, *Science*, vol. 22, p. 97, 1893.

¹⁵ Diller, J. S., *Bull. Geol. Soc. Am.*, vol. 4, pp. 218-220, 1893.

¹⁶ Stanton, T. W., *The Faunal Relations of the Eocene and Upper Cretaceous on the Pacific Coast*, 17th Annual Report, *U. S. Geol. Surv.*, pp. 1011-1059, 1896.

¹⁷ Merriam, J. C., *The Geological Relations of the Martinez Group of California at the Typical Locality*, *Jour. Geol.*, vol. 5, pp. 767-775, 1897.

¹⁸ Anderson, R. V., *Preliminary Report on the Geology and Possible Oil Resources of the South End of the San Joaquin Valley, Cal.*, *Bull. 471, U. S. Geol. Surv.*, pp. 117-119, 1912.

¹⁹ Watts, W. L., *The Gas and Petroleum Yielding Formations of the Central Valley of California*, *Bull. No. 3, California State Mining Bureau*, Aug., 1894, pp. 9-10.

²⁰ Cooper, J. G., *Catalogue of California Fossils*, *Bull. No. 4, California State Mining Bureau*, Sept. 1894, pp. 36-45.

²¹ Lindgren, W., and Turner, H. W., *Marysville Folio*, *U. S. Geol. Surv.*, Folio 17, April, 1895.

region in 1894 and 1895. Cooper in Bulletin No. 4 also described several forms from the Tejon Eocene of San Diego and Coalinga. In a general correlation paper, Dall²² placed both the Martinez and the Tejon as the correlative of the Midway stage of the southeastern United States and the Cernaysian of Europe. Lawson²³ in a general descriptive paper on the geology of Central California described the Tejon group in the Concord Quadrangle.

During the last ten years most of the literature dealing with the Tejon group is in connection with geological mapping and oil investigations. Eldridge and Arnold,²⁴ Arnold,²⁵ Arnold and Robert Anderson,²⁶ Arnold and Johnson,²⁷ F. M. Anderson,²⁸ Dumble,²⁹ Robert Anderson,³⁰ Lindgren,³¹ Dickerson,³² Lawson,³³ McLaughlin and Waring,³⁴ have added to the knowledge of the distribution of the Tejon in California and have incidentally described several new species.

²² Dall, W. H., A Table of the North American Tertiary Horizons correlated with one another and with those of Western Europe, 18th Annual Report, U. S. Geol. Surv., part 2, pp. 327-348, 1898.

²³ Lawson, A. C., A Geological Section of the Middle Coast Ranges of California, Science, n. s., vol. 15, p. 416, 1902.

²⁴ Eldridge, G. H., and Arnold, R., The Santa Clara Valley, Puente Hills and Los Angeles Oil Districts, Southern California, Bull. 309, U. S. Geol. Surv., 1907.

²⁵ Arnold, R., Geology and Oil Resources of the Summerland District, Santa Barbara County, California, Bull. 321, U. S. Geol. Surv., 1907.

²⁶ Arnold, R., and Anderson, Robert, Geology and Oil Resources of the Santa Maria Oil District, Bull. 322, U. S. Geol. Surv., 1907.

²⁷ Arnold, R., and Johnson, H., Preliminary Report on the McKittrick-Sunset Oil Region, Bull. 406, U. S. Geol. Surv., 1910.

²⁸ Anderson, F. M., A Stratigraphic Study in the Mount Diablo Range of California, Proc. Cal. Acad. Sci., 3rd ser., Geology, vol. 2, pp. 156-248, 1905.

A Further Stratigraphic Study in the Mount Diablo Range of California, Proc. Cal. Acad. Sci., 4th ser., vol. 3, 1908.

²⁹ Dumble, E. T., Notes on Tertiary Deposits near Coalinga Oil Field and their Stratigraphic Relations with Upper Cretaceous, Jour. Geol., vol. 20, pp. 28-37, 1912.

³⁰ Anderson, R., Preliminary Report on the Geology of the Oil Prospects of the Cantua-Panoche Region, California, Bull. 431a, U. S. Geol. Surv., 1909.

Preliminary Report on the Geology and Possible Oil Resources of the Southern End of the San Joaquin Valley, Bull. 471a, U. S. Geol. Surv., 1912.

³¹ Lindgren, W., Tertiary Gravels of the Sierra Nevada of California, Professional Paper No. 73, U. S. Geol. Surv., 1911.

³² Dickerson, R. E., Fauna of the Martinez Eocene of California, Univ. Calif. Publ. Bull. Dept. Geol., vol. 8, pp. 61-180, 1914; The Martinez and Tejon Groups and Associated Formations of the Santa Ana Mountains, Univ. Calif. Publ. Bull. Dept. Geol., vol. 8, pp. 257-274A, 1914.

³³ Lawson, A. C., San Francisco Folio, U. S. Geol. Surv. Folio 193, 1914.

³⁴ McLaughlin and Waring, C. A., Petroleum Industry of California and Map Folio to accompany Bull. No. 69, Cal. State Mining Bureau, 1915.





Arnold,³⁵ Pack,³⁶ Dickerson³⁷ and Waring³⁸ have contributed papers dealing with the fauna of the upper Eocene of California.

DESCRIPTIONS OF TYPICAL TEJON AREAS IN CALIFORNIA

TEJON GROUP SOUTH OF MOUNT DIABLO

STRATIGRAPHY

The Tejon group south of Mount Diablo is a northwest-southeast strip about ten miles in length. It has an unconformable relation to the underlying Chico and Martinez. For a distance of six miles this unconformity is marked by basal Tejon strata containing boring shells which penetrate the underlying Chico or Martinez rocks. In some places these borings are found in limestone of Martinez age, again in Chico sandstone and Chico limestone containing fragments of *Inoceramus*. (See Figure 1 and map.)

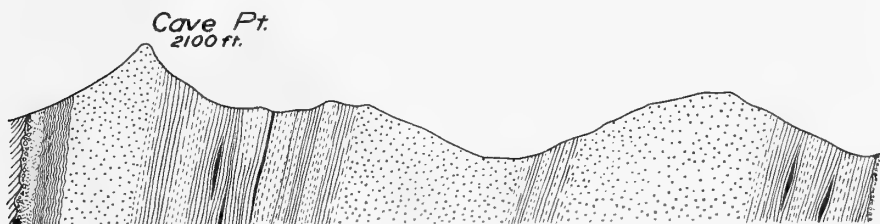


Fig. 1. A North-South section through Cave Point on the north and Oyster Point Ridge on the south. Chico strata are indicated on the extreme left of the figure while Miocene sandstone is shown on the extreme right.

The Tejon is overlain by the Monterey and Oligocene. No difference in dip and strike was found between the Tejon and the overlying formations in this field. An unconformity or disconformity probably exists here. At a locality in the bed of Walnut Creek about one and one-half miles southwest of the town of that name,

³⁵ Arnold, Ralph, Palaeontology of the Coalinga District, Bull. 396, U. S. Geol. Surv., 1909.

³⁶ Pack, R. W., Notes on Echinoids from the Tertiary of California, Univ. Calif. Publ. Bull. Dept. Geol., vol. 5, No. 18, 1910.

³⁷ Dickerson, R. E., Fauna of the Eocene at the Marysville Buttes, California, Univ. Calif. Publ. Bull. Dept. Geol., vol. 7, pp. 257-298, 1913; Note on the Faunal Zones of the Tejon Group, *ibid.*, vol. 8, pp. 12-25, 1914; Fauna of the Martinez Eocene of California, *ibid.*, vol. 8, pp. 61-180, 1914; The Ione Formation of the Sierra Nevada Foothills, Science, n. s., vol. 40, July 10, 1914.

³⁸ Waring, C. A., Eocene Horizons of California, Jour. Geol., vol. 22, pp. 782-785, 1915.

the overlying Oligocene beds contain water-worn fragments of coal and sandstone of probable Tejon age which were evidently derived from the underlying Tejon. Walnut Creek is only a short distance from the Tejon area south of Mount Diablo and conditions are probably the same in both places. (See Figure 2.)

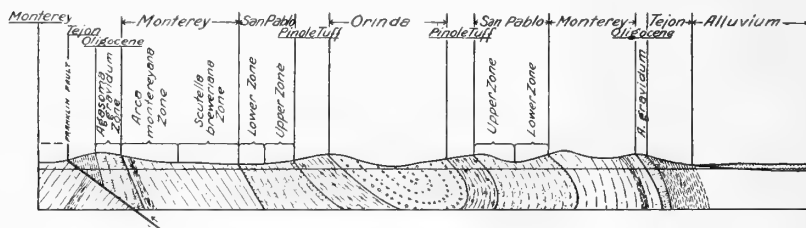


Fig. 2. Section showing Tejon strata and associated rocks in the vicinity of Walnut Creek, Concord Quadrangle. (After Lawson.)

The following section through Cave Point was measured by Mr. William Kew and the writer. Figure 1 shows the relations graphically.

SECTION OF THE TEJON GROUP SOUTH OF MOUNT DIABLO

Chico sandstone and limestone.

	Feet.
(1) Conglomerate	5
(2) Thin-bedded gray sandstone.....	20
(3) Gray foraminiferal shale.....	75
(4) Hard gray sandstone.....	40
(5) Massive tan sandstone.....	20
(6) Gray-green foraminiferal shale.....	25
(7) Light-tan coarse sandstone with cavernous weathering, first bluff	125
(8) Alternating soft sandstones and carbonaceous shales.....	200
(9) Sandstones with interbedded shales.....	307
(10) Thin-bedded sandstone.....	50
(11) Shale with thin-bedded sandstone.....	63
(12) Thin-bedded sandstone with <i>Turritella uvasana</i> beds on top.....	100
(13) Massive soft sandstone with <i>Turritella uvasana</i> beds, second bluff	100
(14) Massive tan sandstone, second bluff.....	390
(15) Shale	100
(16) Light gray sandstone.....	8
(17) Carbonaceous shale and thin-bedded sandstone.....	45
(18) Massive tan sandstone, third bluff.....	554
(19) Carbonaceous shales and lignite.....	25
(20) Massive tan sandstone.....	85
(21) Blue shale.....	25
(22) Massive tan sandstone.....	225

Monterey sandstone

Total2587

LIST OF SPECIES COLLECTED FROM BASAL TEJON STRATA SOUTH OF MOUNT DIABLO

[illegible]

The Tejon on the south side of Mount Diablo is on the average about 2600 feet thick and it has a general strike of N 60° W. In the northwestern portion of the area under discussion, it has a dip of 60° south in Pine Cañon. Going southward along the strike, these strata become vertical and finally overturned in the vicinity of Cave Point, where they have a dip of 70° to 85° N. Two to three miles southeast of Cave Point the Tejon is pinched out by a great overthrust fault. Very extensive collections were made throughout the entire extent of the Tejon. A particularly good section for study was found in an unfaulted area lying between Cave Point and Oyster Point. At least three faunal zones were recognized in this area.

FAUNA

TURBINOLIA ZONE

A very large fauna was obtained from the basal beds. These strata, consisting of four to five feet of irregularly bedded limestone, conglomerate, and hard calcareous sandstone, and about two feet of thin-bedded sandstone, lie unconformably upon the Chico limestone and sandstone. Numerous pholad borings mark this ancient shoreline of the Tejon sea. This same horizon also occurs in the Pacheco syncline near Muir Station, Concord Quadrangle. The last three localities listed below are from this vicinity. A list of species from the Turbinolia Zone is given below:

Nummuloid(?), sp., *Thamnasteria sinuata* Nomland, *Turbinolia pusillanima* Nomland, *Yoldia*(?), sp., *Thracia karquinezensis* Weaver, *Tellina martinezensis* Weaver, *Paphia conradi*, n. sp., *Pholadidea*, sp., *Metula harrisi*, n. sp., *Natica gesteri*, n. sp., *Nyctilochus eocenicus* (Weaver), *Strepsidura howardi*, n. sp., and *Perissolax gabbi*, n. sp., appear to be restricted to this zone. *Modiolus merriami* (Weaver), *Solen stantoni* Weaver, and *Turritella conica* Weaver are forms which occur in the underlying Martinez but are not found in the Tejon of the type locality. *Dosinia elevata* Gabb and *Lucina gyrata* (Gabb), although not characteristic, are very common at this horizon. *Leda gabbi* Conrad makes up a large bulk of the thin-bedded sandstones of this member. The rarity of *Turritella uvasana* Conrad and the absence of *Rimella simplex* Gabb are particularly noteworthy, as

they are the most characteristic forms of the *Rimella simplex* zone of the Tejon group.

Above the basal portion is about twenty-five to fifty feet of a deep-water facies of this zone consisting of fine-grained, gray, foraminiferal shales, which yielded *Pecten interradiatus* Gabb, *Schizaster lecontei* Merriam, *Venericardia planicosta* Lamarek, and several species of foraminifers. These beds, which were evidently deposited in moderately deep water as the presence of glauconite and abundance of *Schizaster lecontei* and foraminifers show, are far better developed in the south limb of Pacheco Syncline, where they have yielded the fauna listed under localities 215, 337, 532. This facies is not quite so well developed south of Mount Diablo as in the Pacheco Syncline.

The stratigraphic position of the beds yielding the *Turbinolia* fauna, the presence of several species which are generally characteristic of the Martinez, the presence of several species which appear to be restricted to the *Turbinolia* zone, and the absence of several characteristic forms common in the *Rimella simplex* zone indicate a life condition which is decidedly closer to the Martinez, the lower Eocene, than that of the Tejon of Cañada de las Uvas. However, the presence of seventy-five or eighty species typical of the Tejon of the type locality connects this fauna with that of the *Rimella simplex* zone and shows that both are zonal phases of the upper Eocene, the Tejon group.

RIMELLA SIMPLEX ZONE

Resting upon the gray-green shales of the *Turbinolia* zone are from one hundred to two hundred feet of massive tan sandstones constituting the first "bluff sandstone". As the name implies, these strata have a very characteristic weathering habit, a tendency to form prominent walls and caves.

Above the first bluff is seven hundred feet of strata made up of alternating thin-bedded sandstones and carbonaceous shales which at places contain thin seams of lignite. This apparently represents several local oscillations of the coast in Tejon time, thus giving rise to marine littoral, brackish, or even fresh-water conditions. Its fauna is the same as the one obtained above the first bluff sandstone. *Turritella andersoni*, n. sp. was found in the upper portion of these beds. This species is also common in the Eocene beds northwest of Coalinga which have been referred to the Martinez, but its occur-

rence here, taken together with other evidence, proves that this reference is incorrect.

The second bluff sandstone of one to two hundred feet overlies the thin-bedded sandstones and carbonaceous shales. It is for the most part non-fossiliferous. In sandstone about one hundred feet above, was obtained a fauna which is similar to that of the first bluff sandstone. The similarity in fauna of these two horizons indicates that the time represented by the seven hundred feet of alternating shales and sandstones and minor unconformities between some of the beds was comparatively short.

Separated from the second bluff by alternating shales and sandstones is the third bluff, consisting of a massive tan rock, weathering in a manner similar to that of the other, but giving outcrops not quite so prominent. This bluff is 550 feet thick and non-fossiliferous in the eastern end but two or three collecting localities occur in equivalent strata in the western portion. These three bluffs and the intervening strata seem to contain but one fauna, and on this account this great thickness is included in the *Rimella simplex* zone. Furthermore, similar conditions are found north of Coalinga and at the type locality of the Tejon.

The lists on pp. 376-377 contain the species which have been found in the *Rimella simplex* zone south of Mount Diablo:

This fauna contains most of the species common in the Tejon. It is characterized by the presence of *Rimella simplex* Gabb, *Venericardia planicosta hornii*, *Turritella uvasana*, *Crassatellites uvasana*, *Conus remondii*, *Whitneya ficus*, and many other forms which are abundant at the type locality of the Tejon. Apparently the same faunal stage is present in both places.

BALANOPHYLLIA VARIABILIS ZONE

The remainder of the Tejon may be grouped as alternations of carbonaceous shales and fine-grained sandstones. Within this upper horizon, extending from 400 to 800 feet below the Monterey contact, are found abundantly fossiliferous strata having for their most characteristic fossil the coral *Balanophyllia variabilis* Nomland, which is associated here with *Schizaster lecontei* and *Cardium cooperii*. This zone appears to be somewhat lower than the uppermost Eocene of the Marysville Buttes region. Some of these strata were deposited in moderately deep water, although carbonaceous deposits found just

LIST OF SPECIES FROM THE RIMELIA SIMPLEX ZONE SOUTH OF MOUNT DIABLO

	106	108	470	471	713	715	726	733	745	1412	1428	1421	1489
<i>Trochocyathus imperialis</i> Nomland.....	×
<i>Trochocyathus striatus</i> Gabb.....	×
<i>Trochocyathus</i> , sp.....	×
<i>Schizaster lecontei</i> Merriam.....
<i>Acila gabbiana</i> , n. sp.....	×
<i>Arca</i> , sp.....	×
<i>Arca clarki</i> , n. sp.....
<i>Arca hornii</i> Gabb.....	×
<i>Cardium cooperii</i> Gabb.....	×	×	×	×
<i>Cardium brewerii</i> Gabb.....	×
<i>Crassatellites uvasana</i> Gabb.....	×
<i>Corbula hornii</i> Gabb.....	×	×	×
<i>Glycimeris sagittata</i> Gabb.....	×
<i>Isocardium tejonensis</i> Waring.....	×
<i>Leda gabbi</i> Conrad.....	×	×	×	×
<i>Lucina cumulata</i> Gabb.....	×
<i>Lucina gyrata</i> (Gabb).....	×
<i>Lucina</i> , sp.....	×	×
<i>Meretrix ovalis</i> Gabb.....	×	×
<i>Meretrix hornii</i> Gabb.....	×	×	×	×	×
<i>Meretrix tejonensis</i> Dickerson.....	×	×	×	×	×	×
<i>Macrocallista conradiana</i> Gabb.....	×	×
<i>Modiolus ornatus</i> Gabb.....	×	×
<i>Ostrea</i> , sp.....	×
<i>Psammobia hornii</i> (Gabb).....	×	×	×	×	×
<i>Piacunanomia inornata</i> Gabb.....	×
<i>Paphia</i> , cf. <i>conradi</i> , n. sp.....	×	×
<i>Pinna barrowsi</i> Dickerson.....
<i>Solen parallelus</i> Gabb.....	×	×
<i>Spisula merriami</i> Packard.....	×	×	×	×	×	×

[illegible]

below them indicate that the land was not in a stable condition at that time. The species obtained from these beds are as follows:

LIST OF SPECIES FROM LOCALITIES IN THE *BALANOPHYLLIA VARIABILIS* ZONE,
SOUTH OF MOUNT DIABLO

	469	477	714	720	725	729	730
<i>Balanophyllia variabilis</i> Nomland.....	×	×	×	×
<i>Trochocyathus striatus</i> (Gabb).....	×
<i>Turbinolia dickersoni</i> Nomland	×
<i>Schizaster lecontei</i> Merriam	×
<i>Arca hornii</i> Gabb.....	✓
<i>Cardium cooperii</i> Gabb.....	×	×	×
<i>Cardium brewerii</i> Gabb	×
<i>Corbula parilis</i> Gabb	×
<i>Corbula hornii</i> Gabb	×	×
<i>Dosinia elevata</i> Gabb	×
<i>Glycimeris sagittatus</i> (Gabb)	×	×
<i>Lucina cumulata</i> Gabb.....	×	×
<i>Leda fresnoensis</i> , n. sp.	✓
<i>Leda gabbi</i> Conrad	×	×	×
<i>Meretrix tejonensis</i> Dickerson	×	×	×
<i>Meretrix hornii</i> Gabb.....	×	×
<i>Macrocallista conradiana</i> (Gabb)	×	×
<i>Modiolus ornatus</i> Gabb	×
<i>Psammobia hornii</i> (Gabb).....	×	×
<i>Spisula tejonensis</i> Packard	×	×
<i>Spisula merriami</i> Packard	×	×	×
<i>Solen</i> , sp.	×
<i>Semele diaboli</i> Dickerson.....	×
<i>Tellina longa</i> Gabb	×	×
<i>Tellina remondii</i> Gabb	✓
<i>Tellina</i> cf. <i>aequalis</i> Gabb	×
<i>Tellina jollaënsis</i> , n. sp.	×
<i>Tellina</i> , sp.	✓
<i>Tellina sutterensis</i> Dickerson	×
<i>Tellina</i> , sp.	×
<i>Venericardia planicosta hornii</i> (Gabb)....	×	✓
<i>Cadulus pusillus</i> (Gabb)	✓
<i>Dentalium stramineum</i> Gabb	×	×
<i>Amauropsis alveata</i> (Conrad)	×	×
<i>Ancillaria elongata</i> Gabb	×	×
<i>Conus</i> , sp.	✓
<i>Conus remondii</i> Gabb	×	×
<i>Conus cowlitzensis</i> Weaver	×
<i>Cylichna costata</i> Gabb	×	×
<i>Cancellaria stantoni</i> Dickerson	×
<i>Chrysodomus supraplicata</i> Gabb	×	×
<i>Ficopsis remondii</i> Gabb	×
<i>Galeodea tuberculata</i> (Gabb)	×	×	×
<i>Lunatia nuciformis</i> Gabb	×

LIST OF SPECIES FROM LOCALITIES IN THE BALANOPHYLLIA VARIABILIS ZONE,
SOUTH OF MOUNT DIABLO—(Continued)

	469	477	714	720	725	729	730
<i>Neverita secta</i> Gabb	×
<i>Nassa antiquata</i> Gabb	×
<i>Nassa cretacea</i> Gabb	×
<i>Nyctilochus hornii</i> (Gabb)	×
<i>Olivella mathewsonii</i> Gabb	×
<i>Pseudoliva lineata</i> Gabb	×
<i>Perissolax blakei</i> (Conrad)	×
<i>Turritella andersoni</i> , n. sp.	×
<i>Turritella uvasana</i> Conrad	×	×
<i>Turritella buwaldana</i> , n. sp.	×	×

The species formerly identified in collections made from this locality and from the Marysville Buttes as *Trochocyathus striatus* Gabb proves to belong to the genus *Balanophyllia* according to Mr. John Nomland, who has made a very careful study of West Coast fossil corals. The species found south of Mount Diablo, which has been described by him under the name of *Balanophyllia variabilis*, appears to be larger, longer and more uniformly horn-shaped than the form, from the Marysville Buttes, which as a rule suddenly enlarges in the upper two-thirds of the corallum. The cross-sections of the two corals appear to be identical. The differences cited may be varietal at least. The true *Trochocyathus striatus* appears to range through both the *Rimella simplex* zone and the *Balanophyllia variabilis* zone, while *Balanophyllia variabilis* ranges through the two upper zones and does not appear in the *Rimella simplex* zone. The absence of several species characteristic of both the *Siphonalia sutterensis* zone above and the *Rimella simplex* zone below are the principal characteristics of this fauna. In other words, this zone is transitional between the second and the uppermost zone of the Tejon group.

Taken as a whole, the 2600 feet of the Tejon south of Mount Diablo may be divided into three main divisions, the lowermost, the middle consisting of the three bluffs and their intervening strata, and the upper. Within these are recognized several faunal zones: (1) *Turbinolia* zone; (2) *Rimella simplex* zone; (3) *Balanophyllia variabilis* zone.

TEJON LOCALITIES OF 1911 SUMMER SCHOOL

All localities in the following list are in the Tejon group, Mount Diablo Quadrangle, Contra Costa County, California.

(Twp. 1 South, Range 1 West, Mount Diablo Base Line and Meridian, unless otherwise specified.)

106. Near SE corner of SE $\frac{1}{4}$ of Sect. 11. Summer School 1911. No. 30. Coll. B. L. Clark.
108. North of center of SW $\frac{1}{4}$ of Sect. 11, NE of Wall Point, elevation about 1400 feet. S. S. 1911. Coll. B. L. Clark.
124. Near NE corner of SW $\frac{1}{4}$ of Sect. 33, Twp. 1 North, R. 1 W, on SW side of creek running to northwest, elevation 575 feet. S. S. 1911. No. 677=1418.
143. NE $\frac{1}{4}$ of Sect. 4, near Chico-Tejon contact. S. S. 1911. No. 682.
342. SW $\frac{1}{4}$ of Sect. 3, in Pine Cañon.
469. Near middle of SE $\frac{1}{4}$ of Sect. 21, elevation 1350 feet, on north side of ridge in Riggs Cañon. S. S. 1912. No. 1321 R. E. D. Coll. R. E. Dickerson.
470. NE $\frac{1}{4}$ of NW $\frac{1}{4}$ of Sect. 21, elevation 1550 feet on Cave Point ridge. S. S. 1912. No. 1317 R. E. D. Coll. R. E. Dickerson.
471. NW $\frac{1}{4}$ of NE $\frac{1}{4}$ of Sect. 20, on first spur to east of saddle between Oyster Point and Cave Point. S. S. 1912. No. 1008 Clark. Coll. B. L. Clark.
472. SW $\frac{1}{4}$ of SE $\frac{1}{4}$ of Sect. 22, elevation 1050 feet, near coal mine. S. S. 1912. No. 1402 Kew and No. 1501 Buwalda. Colls. J. P. Buwalda and Wm. Kew.
473. Middle of range line between Sects. 15 and 16, elevation 1600 feet. S. S. 1912. No. 1310 R. E. D. Coll. R. E. Dickerson.
474. SE corner of NW $\frac{1}{4}$ of NW $\frac{1}{4}$ of Sect. 22, elevation 1350 feet, just above saddle in ridge, south of house and east of road. S. S. 1912. No. 1404 Kew. Coll. Wm. Kew.
475. NE $\frac{1}{4}$ of SE $\frac{1}{4}$ of Sect. 22, elevation 1100 feet, about 150 feet above junction of east branch of creek above house, with creek running east from camp. S. S. 1912. No. 1519 Buwalda. Coll. J. P. Buwalda.
476. SW $\frac{1}{4}$ of NW $\frac{1}{4}$ of Sect. 22, elevation 1200 feet, in little wash near creek, below 1250-foot hill. S. S. 1912. No. 1406 Kew. Coll. Wm. Kew.
477. NW corner of SW $\frac{1}{4}$ of SW $\frac{1}{4}$ of Sect. 22, elevation 1050 feet, on road. S. S. 1912. No. 1407 Kew. Colls. Kew and Dickerson.
478. NE $\frac{1}{4}$ of NW $\frac{1}{4}$ of Sect. 21, elevation 1500 feet, on top of Cave Point Ridge to SE of summit. S. S. 1912. No. 1339 R. E. D. Coll. R. E. Dickerson.
483. NW $\frac{1}{4}$ of NE $\frac{1}{4}$ of Sect. 27, elevation 1100 feet, about 200 feet up hill, SE of coal mine. S. S. 1912. No. 1120 Stoner. Coll. R. Stoner.
701. NE $\frac{1}{4}$ of SE $\frac{1}{4}$ of Sect. 17, elevation 1850 feet, on ridge between Windy and Cave Point. S. S. 1912. No. 1100 Stoner (July 4, 1912). Colls. R. E. Stoner, W. English and J. C. Merriam.
702. NE $\frac{1}{4}$ of NW $\frac{1}{4}$ of Sect. 13, elevation 1750 feet, on N side of Black Hills, W of Wall Point. S. S. 1912. No. 1336 R. E. D. (Supplementary S. S. Map). Coll. R. E. Dickerson.
703. SE $\frac{1}{4}$ of SE $\frac{1}{4}$ of Sect. 11, on road east of 2018-foot hill. S. S. 1912. No. 1336 R. E. D. (Supplementary Map). Coll. R. E. Dickerson.

TWP. 1 SOUTH, RANGE 1 EAST

704. NE $\frac{1}{4}$ of NW $\frac{1}{4}$ of Sect. 20. S. S. 1912. No. 1326 R. E. D. Coll. R. E. Dickerson.
705. NW $\frac{1}{4}$ of SE $\frac{1}{4}$ of Sect. 22, elevation 1300 feet, near top of ridge, east side of Riggs Cañon opposite Oyster Point. S. S. 1912. No. 1510 Packard. Coll. E. L. Packard.
706. NW $\frac{1}{4}$ of SE $\frac{1}{4}$ of Sect. 22, elevation 1000 feet, east side of Riggs Cañon near road running east from cañon. S. S. 1912. No. 1508 Packard. Coll. E. L. Packard.
709. On east side of Cave Point in the basal stratum of the Tejon group. S. S. 1912. Coll. R. E. Dickerson.
713. SE $\frac{1}{4}$ of SE $\frac{1}{4}$ of Sect. 17, elevation 1900 feet, on S side of Cave Point, a little east of 2100-foot hill. S. S. 1912. No. 1007 B. L. Clark. Coll. B. L. Clark.
714. NE $\frac{1}{4}$ of SE $\frac{1}{4}$ of Sect. 21, elevation 1250 feet, Riggs Cañon, N of Oyster Ridge. S. S. 1912. No. 1328 R. E. D. Coll. R. E. Dickerson.
715. NE $\frac{1}{4}$ of NE $\frac{1}{4}$ of Sect. 21, elevation 1250 feet, Riggs Cañon, about $\frac{1}{2}$ mile N of Oyster Point Ridge. S. S. 1912. No. 1329 R. E. D. Coll. R. E. Dickerson.
717. NW $\frac{1}{4}$ of NW $\frac{1}{4}$ of Sect. 26, elevation 1450 feet, $\frac{1}{2}$ mile NE of 1594-foot hill, on ridge NW of divide. S. S. 1912. No. 1422 Wm. Kew. Coll. Wm. Kew.
718. SW $\frac{1}{4}$ of SE $\frac{1}{4}$ of Sect. 22, elevation 1950 feet, 150 feet E of road. S. S. 1912. No. 1518 Packard. Coll. E. L. Packard.
719. NE $\frac{1}{4}$ of NE $\frac{1}{4}$ of Sect. 27, elevation 1000 feet, 50 feet above creek on right bank, 150 feet from section fence. S. S. 1912. No. 1533 R. E. D. Coll. R. E. Dickerson.
720. NE $\frac{1}{4}$ of NE $\frac{1}{4}$ of Sect. 27, elevation 1250 feet, on ridge leading N from 1594-foot hill. S. S. 1912. No. 1417 Kew. Coll. Wm. Kew.
722. NW $\frac{1}{4}$ of SE $\frac{1}{4}$ of Sect. 22, elevation 1300 feet. S. S. 1912. No. 1349 R. E. D. Coll. R. E. Dickerson.
723. On section line between Sections 15 and 16, near middle of line, elevation 1600 feet, on W hillside about 300 yards SE of road at the divide between Riggs Cañon, W of road, N of Oyster Point Ridge. S. S. 1912. No. 1419 Kew. Coll. Wm. Kew.
725. SE $\frac{1}{4}$ of SE $\frac{1}{4}$ of Sect. 21, on E line of section, elevation 1250 feet, Riggs Cañon, W of road, N of Oyster Point Ridge. S. S. 1912. No. 1320 R. E. D. Colls. E. Brainerd and R. E. Dickerson.
726. NE $\frac{1}{4}$ of SE $\frac{1}{4}$ of Sect. 21, elevation 1250 feet, Riggs Cañon, W of road and N of Oyster Point Ridge. S. S. 1912. No. 1337 R. E. D. Coll. R. E. Dickerson.
727. Center of NW $\frac{1}{4}$ of Sect. 21, elevation 1400 feet, 100 feet above bottom of cañon, and 100 feet above base of second bluff, between Cave Point and Oyster Point. S. S. 1912. No. 1341 R. E. D. Coll. R. E. Dickerson.
728. SE corner of NE $\frac{1}{4}$ of Sect. 21, elevation 1050 feet, Riggs Cañon, W of road, at intersection of creek between Oyster Point and Cave Point and the main creek. S. S. 1912. No. 1316 R. E. D. Coll. R. E. Dickerson.
729. SW $\frac{1}{4}$ of SW $\frac{1}{4}$ of Sect. 22, elevation 1100 feet, Riggs Cañon, 250

- feet W of road and E of Oyster Point. S. S. 1912. No. 1343 R. E. D. Coll. R. E. Dickerson.
730. SE $\frac{1}{4}$ of NW $\frac{1}{4}$ of Sect. 21, elevation 1350 feet, 100 feet above base of second bluff, N of Oyster Point. S. S. 1912. No. 1342 R. E. D. Coll. R. E. Dickerson.
731. SW $\frac{1}{4}$ of SE $\frac{1}{4}$ of Sect. 22, elevation 900 feet in creek bottom. S. S. 1912. No. 1348 R. E. D. Coll. R. E. Dickerson.
732. Center of S $\frac{1}{2}$ of Sect. 22, elevation 1400 feet, E side of Riggs Cañon, just below top of hill on ridge leading south. S. S. 1912. No. 1409 Kew. Coll. Wm. Kew.
733. Middle of E half of SE $\frac{1}{4}$ of Sect. 22, elevation 1150 feet on E side of Riggs Cañon on ridge above barn in cañon. S. S. 1912. No. 1410 Kew. Coll. Wm. Kew.
734. SE $\frac{1}{4}$ of SW $\frac{1}{4}$ of Sect. 22, elevation 1200 feet, E side of Riggs Cañon, above coal mine on top of ridge SW edge of hill. S. S. 1912. No. 1412 Kew. Coll. Wm. Kew.
745. NE corner of Sect. 20, on ridge running S from Cave Point, 100 feet above base of second bluff. S. S. 1912. No. 1340 R. E. D. Coll. R. E. Dickerson.
756. NW $\frac{1}{4}$ of SW $\frac{1}{4}$ of Sect. 22, elevation 1250 feet in white bluff on road $\frac{1}{4}$ mile above camp. S. S. 1912. No. 1418 Kew. Coll. Wm. Kew.
769. NW $\frac{1}{4}$ of NE $\frac{1}{4}$ of Sect. 21, nearly due west of house, elevation 1300 feet. S. S. 1912. No. 1205 Stoner. Coll. R. C. Stoner.

TWP. 1 SOUTH, RANGE 1 WEST

1412. Near NE corner of NW $\frac{1}{4}$ of Sect. 10, on S side of Pine Cañon, elevation 900 feet.
1415. SE $\frac{1}{4}$ of NE $\frac{1}{4}$ of Sect. 10, elevation about 450 feet, N of Wall Point.
1417. NE corner of NW $\frac{1}{4}$ of Sect. 10, near head of Pine Cañon, elevation 850-900 feet. S. S. 1911. No. 353.
- 1418=124.
1420. Near center of NE $\frac{1}{4}$ of Sect. 10, elevation 750 feet, in basal member of Tejon.
1421. SE corner of NE $\frac{1}{4}$ of Sect. 32, Twp. 1 North, Range 1 West, on ridge E of Pine Cañon, elevation 650 feet. S. S. 1911. No. 673.
- 1427=108.
1428. On E line of SW $\frac{1}{4}$ of Sect. 11. S. S. 1911. No. 53.
1429. On E side of road near SW corner of SW $\frac{1}{4}$ of Sect. 12. S. S. 1911. No. 29.
1430. SE $\frac{1}{4}$ of Sect. 11, on N side near top of 2018-foot hill in basal member of Tejon. S. S. 1911. No. 57.
1432. Near S line of NW $\frac{1}{4}$ of Sect. 11, near head of Pine Cañon, elevation about 1250 feet. S. S. 1911. No. 25.
1489. On S side of Pine Cañon on branch road crossing over ridge to Danville about 200 feet above bottom of Pine Cañon on W line of S W $\frac{1}{4}$ of SW $\frac{1}{4}$ of Sect. 3. S. S. 1911. No. 329.

THE TEJON GROUP NORTH OF MOUNT DIABLO
STRATIGRAPHY

The Tejon north of Mount Diablo is a strip which is on the average a mile in width and several miles in length. It consists of

a thick basal conglomerate resting unconformably upon Chico-Martinez rocks, white to dull red sandstone with subordinate shale beds, and three coal seams interbedded with soft shales and white sandstones. Its upper limits have not been certainly discovered, but there is a sudden change in lithology north of the village of Somersville which may mark a division line between it and the overlying brown carbonaceous sandstones of possible Oligocene age.

The Martinez group in this vicinity is represented surficially by a strip averaging one-quarter of a mile wide which extends from lower Oil Creek westward for four miles. Its west end is terminated by a cross-fault, while its eastern end is cut off by the Tejon conglomerate.

Throughout the area studied there is a constant difference in strike between the Martinez and the Tejon. This is generally ten degrees, and in lower Oil Cañon it is much greater. This difference in strike causes the Tejon conglomerate to rest upon a stratum of hard Martinez sandstone at one locality and upon soft Martinez shales at another. This accounts for a very irregular Martinez-Tejon contact.

The dip of the Martinez throughout the field is greater than that of the Tejon. The basal Tejon conglomerate, which is from ten to twenty feet thick, rests upon the Martinez sandstones and shales and forms a well-defined bed for over four miles in length. It consists of very coarse pebbles and boulders, which make it easily separable from the sandstones of the Martinez. The pebbles and boulders are in most places quartzose, but fragments of fossiliferous limestone, and sandstone and igneous rocks also occur. *Nucula truncata*, *Cylichna costata*, *Modiolus cylindricus*(?), *Dentalium cooperii*, and mollusc-bored boulders which resemble very closely the pholad borings on the Martinez-Chico contact described below, have been obtained from limestone and sandstone boulders imbedded in the conglomerate. Either the Chico or Martinez groups supplied this material, or possibly both may have contributed to this basal Tejon, as these species are limited to the upper Cretaceous and the Eocene on this coast.

The evidence of unconformity between the Martinez and the Tejon groups in the region north of Mount Diablo is based (1) upon areal mapping of the beds containing characteristic faunas of these groups, (2) upon variation of strike at the contact, (3) upon variation in dip throughout the area studied; (4) upon the presence of

a conglomerate which marks a very decided change in sedimentation at the base of the Tejon. (See Fig. 3.)



Fig. 3. North-south section showing relations of Chico, Martinez and Tejon in the region north of Mount Diablo, near Stewartville.

FAUNA

The principal fossiliferous horizon in the Tejon north of Mount Diablo occurs above the coal strata in the vicinity of the old coal mining village, Somersville. Stanton³⁹ described this locality as follows:

The contact between the Chico and the Tejon was not found exposed at any place near the coal mines east of Clayton, but it is evident that the coal beds are not far above the base of the Tejon. Gabb reports the occurrence of *Cucullaea mathewsonii* and *Fasciolaria laeviuscula* in the "intermediate beds" beneath the coal near Clayton, thus indicating a horizon much better represented by fossils near Pacheco, Benicia, and Lower Lake. At Summersville, one of the coal-mining villages east of Clayton, an undescribed species of *Corbicula* occurs abundantly in a layer beneath the lower coal bed.

The beds associated with and immediately overlying the coal consist mostly of light-colored, rather coarse, friable sandstone, 400 or 500 feet in thickness. In most of the exposures examined they are fossiliferous only in the upper part, where they contain a typical Tejon fauna like that described from Fort Tejon. Probably the lowest of these fossiliferous horizons above the coal is exposed in a low hill just west of Summersville and south of the cemetery, in sandstones not more than 100 feet above the principal coal bed mined there, and perhaps 300 feet above the base of the sandstones. The following species have been identified in the collection from this place:

<i>Modiola ornata</i> Gabb	<i>Pectunculus sagittatus</i> Gabb
<i>Venericardia planicosta</i> Lam.	<i>Cardium cooperi</i> Gabb
<i>Lucina gyrata</i> (Gabb)	<i>Solen parallelus</i> Gabb
<i>Corbula parillis</i> Gabb	<i>Meretrix uvasana</i> Conrad?
<i>Tellina hoffmaniana</i> Gabb	<i>Corbula hornii</i> Gabb
<i>Turritella uvasana</i> Conrad	<i>Amauropsis alveata</i> (Conrad)
<i>Solarium cognatum</i> (Gabb)	<i>Rimella macilenta</i> White
<i>Ficopsis remondi</i> Gabb	<i>Fusus californicus</i> Conrad
<i>Aturia mathewsoni</i> Gabb?	

The Tejon strata, dipping strongly northward, may be traced almost continuously from Summersville west toward Clayton for three or four

³⁹ Stanton, T. M., The Faunal Relations of the Eocene and Upper Cretaceous on the Pacific Coast, 17th Annual Report, U. S. Geol. Surv., pp. 1011-1059, 1896.

miles, and fossils evidently belonging to the same fauna with those named above are abundant at several places at horizons apparently all somewhat above that at Summersville and ranging through a thickness of several hundred feet. One of the most prolific of these localities is on a hill south of the Clayton-Summersville road and about 2½ miles N 35° E of Clayton, where the following species were obtained:

Leda gabbi (Conrad)	Fusus diaboli Gabb
Nucula (Acila) truncata Gabb	Perissolax blakei (Conrad)
Crassatella grandis Gabb	Pleurotoma (Drillia) raricostata Gabb
Crassatella uvasana Conrad	Bela clathrata Gabb
Tellina hoffmaniana Gabb	Fusus occidentalis Gabb
Meretrix uvasana Conrad	Pleurotoma, sp.
Lunatia nuciformis Gabb	Ficopsis remondi Gabb
Lunatia hornii Gabb	Conus remondi Gabb
Galerus excentricus Gabb	Olivella mathewsoni Gabb
Solarium cognatum (Gabb)	Cylichna costata Gabb

At other localities a little farther west, where smaller collections were made, many of the same species were obtained, together with a few others, such as—

Venericardia planicosta Lam.	Dentalium stramineum Gabb
Mysia polita Gabb	Tritonium hornii Gabb
Neaera dolabraeformis Gabb	Ficopsis hornii Gabb
Gadus pusillus Gabb	Megistostoma striata Gabb

The fauna represented by these lists is clearly the original Tejon fauna that occurs in the neighborhood of Fort Tejon, New Idria, and elsewhere along the coast ranges to Washington. Its Eocene character has been recognized by Conrad, Marcou, Heilprin, White and others.

Dr. Stanton evidently studied the Tejon in the vicinity of Clayton and “Summersville” but not south of Stewartville. In the area along the Clayton-Somersville road the Tejon has been brought in contact with the Chico by a strike or oblique fault which has faulted out all the Martinez and about 2000 feet of Tejon strata beneath the coal horizon.

The collections in the California Academy of Sciences from this vicinity contain the following species:

LIST OF SPECIMENS FROM BALANOPHYLLIA VARIABILIS ZONE, NORTH OF MOUNT DIABLO

	259	261
Spatangus(?) pachecoensis Pack.....	...	×
Balanophyllia variabilis Nomland.....	×	...
Flabellum californica Vaughan.....	×	✓
Stephanophyllia californica Nomland.....	×	...
Turbinolia dickersoni Nomland.....	...	×
Trochocyathus striatus (Gabb)	×	✓
Trochocyathus stantoni Vaughan	×	...
Acila gabbiana, n. sp.	×	...

LIST OF SPECIMENS FROM BALANOPHYLLIA VARIABILIS ZONE, NORTH OF MOUNT

DIABLO—(Continued)

	259	261
<i>Corbula parilis</i> Gabb	×	×
<i>Corbula hornii</i> Gabb	×	×
<i>Cardium cooperii</i> Gabb	×	×
<i>Crassatellites uvasana</i> Conrad	×	—
<i>Diplodonta parilis</i> (Gabb)	×	—
<i>Glycimeris sagittatus</i> (Gabb)	×	×
<i>Leda gabbi</i> Conrad	×	×
<i>Leda vaderensis</i> Dickerson	×	—
<i>Meretrix hornii</i> Gabb	×	×
<i>Meretrix ovalis</i> Gabb	×	—
<i>Meretrix tejonensis</i> Dickerson	×	—
<i>Meretrix</i> , cf. <i>gabbi</i> Arnold	×	—
<i>Solen parallelus</i> Gabb	×	—
<i>Spisula merriami</i> Packard	×	—
<i>Tellina sutterensis</i> Dickerson	×	—
<i>Tellina jollaënsis</i> , n. sp.	×	×
<i>Tellina joaquinensis</i> Arnold	×	—
<i>Tellina remondii</i> Gabb	—	×
<i>Venericardia planicosta hornii</i> (Gabb)	×	—
<i>Dentalium stramineum</i> Gabb	×	—
<i>Actaeon moodyi</i> , n. sp.	—	×
<i>Architectonica cognata</i> Gabb	×	×
<i>Amauropsis alveata</i> (Conrad)	—	×
<i>Bullaria hornii</i> Gabb	×	—
<i>Cylichna costata</i> Gabb	×	×
<i>Cancellaria stantoni</i> Dickerson	×	—
<i>Conus</i> , cf. <i>hornii</i> Gabb	×	—
<i>Conus remondii</i> Gabb	—	×
<i>Drillia raricostata</i> Gabb	×	—
<i>Exilia perkinsiana</i> (Cooper)	×	—
<i>Fusinus mathewsonii</i> Gabb	—	×
<i>Fusinus merriami</i> , n. sp.	×	—
<i>Ficopsis remondii</i> Gabb	×	—
<i>Megistostoma striata</i> Gabb	—	×
<i>Natica hannibali</i> Dickerson	—	×
<i>Perissolax blakei</i> (Conrad)	×	×
<i>Rimella canalifera</i> Gabb	—	×
<i>Turritella kewi</i> , n. sp.	×	—
<i>Turritella uvasana</i> Conrad	×	×
<i>Turritella uvasana bicarnata</i> Dickerson	—	×
<i>Turris</i> , sp.	×	—
<i>Cancer</i> (?), sp.	—	×

Cal. Acad. Sci. Locality No. 259. Mount Diablo Quadrangle, Tejon Group. Two miles N 60° E of Clayton, about 100 feet (stratigraphic) above the coal seam and 100 feet below a shale bed. Colls. C. L. Moody, J. O. Nomland and R. E. Dickerson.

Cal. Acad. Sci. Locality No. 261. Mount Diablo Quadrangle, Tejon Group. One fourth mile south of Somersville cemetery, in sandstone about 100 feet above coal seam. Colls. B. L. Clark and class, and R. E. Dickerson.

This fauna evidently represents the *Balanophyllia variabilis* zone on the northern limb of the Mount Diablo Anticline.

IONE FORMATION OF CALIFORNIA

One of the numerous problems of California geology is the correlation of the Tertiary of the Sierra Nevada with that of the Coast Ranges. Many geologists since the time of Whitney have written on the age of the Auriferous Gravels and the associated formations, but the ages of these formations are still in question and their correlation with the marine deposits of the coast ranges is unproven.

While collecting during the past four years for the Department of Palaeontology of the University of California, the writer has had opportunity for the study of the relationship of the Ione of the Sierra Nevada with the marine Eocene of the Coast Ranges. His conclusions are based upon visits to five typical Ione localities, viz., Marysville Buttes, Sutter County, California; vicinity of Oroville South Table Mountain; Merced Falls; vicinity of Bear Creek, Merced County; and the type locality near the town of Ione in the Jackson Quadrangle.

Conclusions from this study are, that the Ione is, in part at least, marine and of Tejon-Eocene age. Marine fossils have been found in the upper portion of the Ione formation in the four localities visited. Apparently the same faunal zone, the *Siphonalia sutterensis*⁴⁰ zone, is represented in these five places.

In the study of the Eocene of the Marysville Buttes the writer's conclusion was that "the supposed marine Ione of Marysville Buttes is evidently Eocene." In the "Note on the Faunal Zones of the Tejon Group," the strata beneath the Older Basalt of Oroville South Table Mountain, which Lindgren mapped as Ione, were correlated with the Eocene of the Marysville Buttes. Several of the fossils obtained from the strata beneath the Older Basalt were identical with those of the Marysville Buttes. After visiting these two localities the writer was inclined to the belief that the Ione and Tejon had been confused in both these places. Conclusive evidence has recently been obtained in the type locality of the Ione which demonstrates that the Ione is merely a local facies of the Tejon-Eocene.

⁴⁰ Dickerson, R. E., Fauna of the Eocene at Marysville Buttes, California, Univ. Calif. Publ. Bull. Dept. Geol., vol. 7, pp. 257-298, 1913. Note on the Faunal Zones of the Tejon Group, Univ. Calif. Publ. Bull. Dept. Geol., vol. 8, p. 23, 1914.

During a recent visit to the Marysville Buttes the writer obtained evidence that the Ione as mapped in the Marysville Folio⁴¹ consists of Chico Cretaceous, Tejon Eocene, and a formation made up of rhyolitic tuff, conglomerates, and thin flows of igneous rock evidently derived from vents which are now represented by volcanic necks designated on the map as "Nr." This last formation rests with marked unconformity upon the two older terranes mentioned and is in turn unconformably overlain by andesitic flows of a later period.

THE EOCENE OF OROVILLE SOUTH TABLE MOUNTAIN

LOCATION

In a recent paper entitled "The Fauna of the Eocene at Marysville Buttes," the writer⁴² recognized a new faunal zone in the Tejon group of California and identified the supposed marine Ione of the Marysville Buttes as Tejon Eocene. The study of the sediments beneath the Older Basalt has resulted in the recognition of these sediments as Tejon Eocene of the same age as the uppermost Eocene of the Marysville Buttes, the *Siphonalia sutterensis* zone. These sediments are littoral deposits, the inshore equivalents of the sediments deposited in the deeper waters of the Marysville Buttes region during Eocene time.

The Eocene strata outcrop near the town of Oroville on the west side of the Sacramento Valley. These strata have been previously regarded as Miocene and were mapped as the Ione Formation by Lindgren. The principal fossil localities are located about two and one-half miles north of the town on the south side of Oroville South Table Mountain, a flat-topped hill, 1050 feet in elevation. (See Plate 43, Figs. 1 and 2.) The beds in which the fossils are found are nearly horizontal. In some places they have a dip of about one degree to the southwest. They rest upon rocks of Chico age and upon the bedrock complex of the Sierra Nevada, and are capped by a basaltic lava flow which varies in thickness from fifty to two hundred feet. Oroville Table Mountain and the South Mountain, with other and smaller flat-topped hills in the vicinity, are remnants of an extensive flow which, according to Turner, came from a point about twenty or thirty miles to the east. The name Older Basalt was given to this lava on the geological map of the

⁴¹ Lindgren, W., and Turner, H. W., Marysville Folio, U. S. Geological Survey, Folio 17, 1895.

⁴² Dickerson, Roy E., The Fauna of the Eocene at Marysville Buttes, California, Univ. Calif. Publ. Bull. Dept. Geol., vol. 8, pp. 257-298, 1913.

Bidwell Bar Folio, just east of this area. Oroville South Table Mountain is about thirty miles northeast of the Marysville Buttes, which are located in the center of the Sacramento Valley.

HISTORICAL

The region north of Oroville has been described in several of the reports of the California State Mining Bureau⁴³ in connection with the extensive hydraulic mines of that locality. Diller⁴⁴ and Turner⁴⁵ have described portions of it and Lindgren,⁴⁶ in a recent paper summarizing all the previous work, has given detailed descriptions of several mines of this area and published a geological map of a portion of the Chico Quadrangle. In this paper, the strata beneath the Older Basalt of South Table Mountain are mapped as Ione.

The first determinative fossils found in the sedimentary beds beneath the Older Basalt were obtained by Mr. O. W. Jasper, a mining engineer, who sent a collection of marine fossils to the University of California from Oroville about fifteen years ago. He described the locality as follows: "The collection of fossils referred to were taken from a mine, . . . located at the south end of South Table Mountain about two miles northeasterly from Oroville. The tunnel from which the collection came was in about 2000 feet under the mountain." This collection contained *Venericardia planicosta merriami*, *Barbatia morsei*, and two new species which have since been found in the Eocene at the Marysville Buttes and described as *Turritella merriami* and *Siphonalia sutterensis*. Mr. Harold Hannibal collected fossils from the strata beneath the Older Basalt in the spring of 1913. Mr. J. H. Ruckman and the writer visited Oroville South Table Mountain in November, 1913, made a brief study of the stratigraphy and collected fossils from several localities. Professor J. P. Smith in 1909 in a short paper, "Salient Events in the Geological History of California", published

⁴³ Preston, E. B., Eleventh Annual Report, California State Mining Bureau, p. 155, 1895.

⁴⁴ Diller, J. S., Tertiary Revolution in the topography of the Pacific Coast, Fourteenth Annual Report, U. S. Geological Survey, pt. 2, p. 418, 1894.

⁴⁵ Turner, H. W., The Rocks of the Sierra Nevada, Fourteenth Annual Report, U. S. Geological Survey, pt. 2, p. 463, 1894; Further contribution to the geology of the Sierra Nevada, Seventeenth Annual Report, U. S. Geological Survey, pt. 1, p. 541, 1896.

⁴⁶ Lindgren, W., Tertiary Gravels of the Sierra Nevada of California, Professional Paper 73, U. S. Geol. Survey, pp. 86-90, 1911.

in *Science*, suggested an Eocene age for the Ione and associated formations.

STRATIGRAPHY

The base of the Eocene strata of South Table Mountain is exposed in the old Miocene Hydraulic Mine, one mile north of Oroville. The basal conglomerate, about twenty feet in thickness, rests upon Chico rocks from which Mr. Ruckman obtained specimens of *Trigonia evansana*, and *Cucullaea*, sp. Twenty feet of clay strata rest upon this conglomerate. These two lithologic members were recognized in the Rumble Mine, one-half mile northwest of this locality, at County Hospital Hill, one mile west, and in the Dyer mining shaft, two and one-half miles north of Oroville. A study of the sediments as exposed in the Dyer shaft and the south face of South Table Mountain gives in descending order the following approximate sequence:

	Feet
(9) Older basalt.....	100 to 150
(8) Andesitic tuff breccia.....	10 to 20
(7) Alternating sandstone, clay and carbonaceous shales.....	100
(6) Conglomerate	50
(5) Tuffaceous clay.....	20
(4) Yellow, tan sandstone.....	100
(3) Dark gray shales interbedded with lignite containing fossiliferous strata, and thin-bedded fossiliferous sandstone	40
(2) Clay with tuff fragments.....	20
(1) Conglomerate resting upon Chico sandstone.....	20

The remaining sedimentary series on the west side of Oroville Table Mountain and South Table Mountain are composed of similar sediments and are beyond doubt the same as those south of South Table Mountain. Turner⁴⁷ reports finding *Corbicula*, sp. in these strata at a point about one and one-half miles south of Pentz (formerly called Pence's Ranch), where they rest upon Chico rocks which contain a very abundant upper Cretaceous fauna.

The conditions of sedimentation in Morris Ravine and at the Cherokee mine have been described admirably by Lindgren⁴⁸ as follows:

The well-known Cherokee hydraulic mine . . . is situated at the north end of Table Mountain. . . . The bedrock of the channel mined

⁴⁷ Turner, H. W., The Rocks of the Sierra Nevada, Fourteenth Ann. Rept., U. S. Geol. Survey, pt. 2, p. 463, 1894.

⁴⁸ Lindgren, W., Tertiary Gravels of the Sierra Nevada of California, pt. 2, p. 90, 1911.

is exposed for about 4400 feet, and in this distance the descent is 250 feet in a west-southwest direction. The form is that of a flat trough, the bedrock rising on the south side 150 feet and on the north side 200 feet and being laid bare throughout. . . . The bottom of the channel is on the whole flat and 700 feet wide. The bedrock is very irregular in detail and covered by large greenstone boulders. The elevation at the upper or east end is about 1250 feet; at the lower end, at the hydraulic bank, about 1000 feet. This channel is not the bed of a main river but rather that of a broad and steep gulch. . . .

At the present bank the channel appears to turn southward and its downward course is in doubt. The gravels at Morris Ravine are of a different character. The upper continuation of this channel is likewise in doubt. It is believed that its source was somewhere near Yankee Hill, where there are rich pocket mines, but there are many such deposits in the immediate vicinity, especially near Oregon City, which could supply the gold for concentration in the Cherokee channel. . . . Along the east front of Table Mountain the basalt generally rests on bedrock at an elevation of about 1000 feet. A sharp Neocene slope of 500 feet in a mile carries the bedrock down from Monte de Oro to Morris and Chambers ravines, where several hydraulic and drift mines are located on bodies of gravel once overlain by the basalt of Table Mountain. The elevation of the bedrock at the diggings above the roadhouse on the point of South Table Mountain is 750 feet. On this point an area of about 900 by 150 feet along the rim has been washed. The rim rises 50 feet on each side, forming a distinct shallow trough. The bedrock is greenstone. The bank is 100 feet high, showing 50 feet of white sand with extremely well-washed pebbles, mainly of quartz. The sand shows fine fluvialite stratification. This is covered by 50 feet of yellowish clay in horizontal beds and this in turn by basalt. From this point the bedrock remains near an elevation of 620 feet almost to the Yuba mine, where it sharply drops to 580 feet. Here there is a considerable hydraulic pit, showing a bank of fine quartz sand with pebbles, underlain by yellowish material containing many pebbles of diabase. . . . Just below this pit, at an elevation of 565 feet, the Yuba tunnel extends a few hundred feet in a westerly direction. A slight incline carries it down to bedrock 20 feet below the portal; at this point the bedrock still pitches into the hill. . . .

A short distance north of the Yuba mine, on the road toward the Goodall and Perkins mine, the Old Glory shaft is sunk 160 feet deep to the greenstone bedrock, which lies at an elevation of about 510 feet and slopes gently west. Coarse, partly angular greenstone gravel was found, apparently containing little gold. The shaft is dry.

A large hydraulic cut has been made at the Goodall and Perkins mine in the clays and fine gravels of the Ione formation, showing a lowest bedrock elevation of about 560 feet. An incline sunk on the rim between the Old Glory shaft and the Goodall and Perkins mine is said to have found bedrock 100 feet lower than in the Old Glory. . . .

No bedrock has been found east of these exposures. Heavy masses of clay, with fossil wood, prevail in the south branch of Chambers Ravine.

There seems to be no large, well-defined channel in Morris Ravine, but an even, rather sharp westward slope, which contained several gullies in which coarser and finer gravel accumulated. They certainly do not represent the continuation of the Cherokee channel.

As shown by Lindgren's descriptions given above, the eastern extent of the sediments mapped as Ione rest upon a very irregular surface cut in the bedrock series. Several different stream channels were recognized by him and he has clearly shown that the sediments of Morris Ravine and the Cherokee mine are principally of fluvial origin. These sediments are the stream-laid deposits which were being deposited at the same time as the marine strata along the shore line a short distance further west.

The conditions in the eastern half and in the western half of the sedimentary beds beneath the Older Basalt differ very decidedly. No stream deposits were observed upon the western side, but the strata appear to be continuous, whereas on the eastern side the sediments were deposited in definite stream-channels. During Eocene times there were several short, consequent, high-grade southward and westward flowing streams which plunged quickly into the Tejon sea, whose shore line must have been located about half-way between the south slope of South Table Mountain and Morris Ravine. The approximate position of this strand line is indicated upon the map (see fig. 4), which is after Lindgren.

FAUNAL RELATIONSHIPS

Mr. Ruckman and the writer obtained the following species from two localities which were located about a mile north of the Butte County Hospital.

LIST OF THE FAUNA FROM THE EOCENE OF OROVILLE SOUTH TABLE MOUNTAIN

<i>Turritella merriami</i> Dickerson	<i>Acmaea ruckmani</i> , n. sp.
<i>Chrysodomus martini</i> Dickerson	<i>Spisula tejonensis</i> , n. sp. Packard
<i>Turris perkinsiana</i> (Cooper)	<i>Acila gabbiana</i> , n. sp.
<i>Turris inconstans</i> (Cooper)	<i>Arca hornii</i> Gabb
<i>Drillia ullreyana</i> Cooper	<i>Barbatia</i> , sp. a.
<i>Drillia orovillensis</i> , n. sp.	<i>Barbatia morsei</i> Gabb
<i>Murex</i> (<i>Ocenebra</i>) <i>nashi</i> , n. sp.	<i>Ostrea</i> , sp. a.
<i>Nyctilochus thunani</i> , n. sp.	<i>Ostrea</i> , cf. <i>appressa</i> Gabb
<i>Cerithiopsis orovillensis</i> , n. sp.	<i>Venericardia planicosta merriami</i>
<i>Turris monolifera</i> (Cooper)	Dickerson
<i>Surcula clarki</i> Dickerson	<i>Modiolus ornatus</i> (Gabb)
<i>Siphonalia sutterensis</i> Dickerson	<i>Meretrix hornii</i> Gabb
<i>Neverita secta</i> Gabb	<i>Placunanomia inornata</i> Gabb
<i>Neverita globosa</i> Gabb	<i>Phacoides cretacea</i> (Gabb)
<i>Lunatia nuciformis</i> Gabb	<i>Leda gabbii</i> Conrad
<i>Nyctilochus diegoensis</i> (Gabb)	<i>Tellina</i> , sp.
<i>Cancellaria stantoni</i> Dickerson	<i>Tellina longa</i> Gabb
<i>Cordia gracillima</i> Cooper	<i>Teredo</i> , sp.
<i>Spirogyphus</i> , sp.	<i>Solen parallelus</i> Gabb
<i>Architectonica</i> , cf. <i>cognata</i> Gabb	

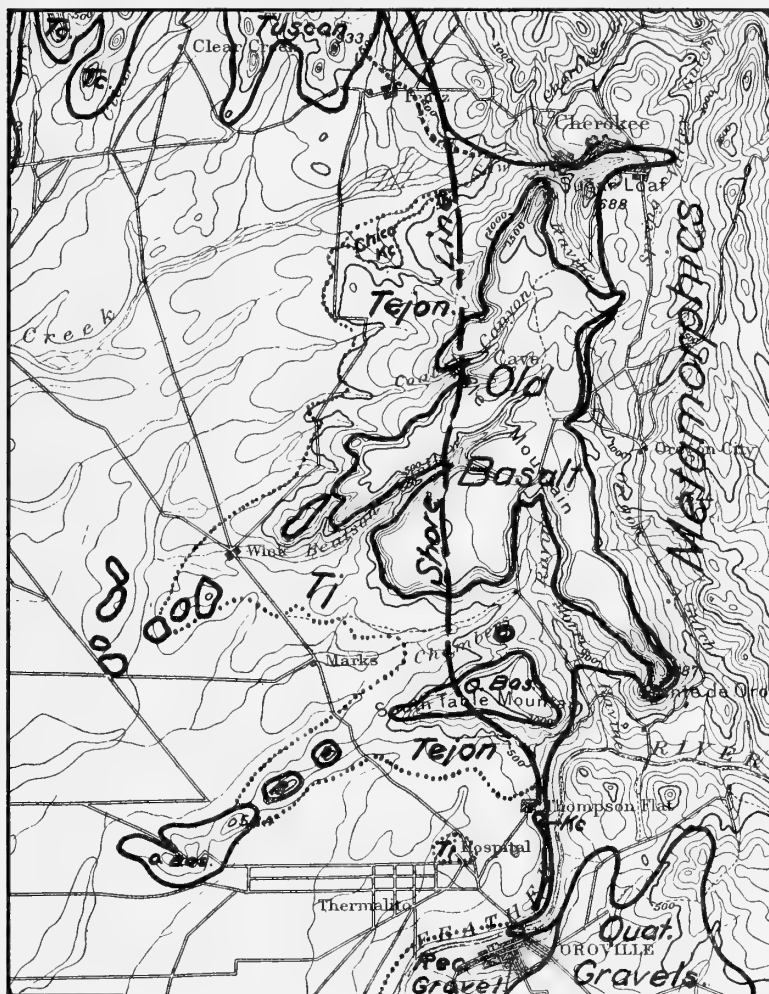


Fig. 4. Geological Map of Oroville and Table Mountain, a portion of the Chico Quadrangle. Adapted from Lindgren. Scale, $\frac{1}{2}$ inch—1 mile.

In a recent paper⁴⁰ the writer discussed the faunal relationships as follows (p. 24):

With the exception of the new species noted in this list, practically all the forms occur in the fauna of the Marysville Buttes, and the most characteristic of these species, *Siphonalia sutterensis*, *Chrysodomus martini*, and *Drillia ullreyana* are found at both localities. Another characteristic feature of this fauna is the peculiar association of the Pleurotomidae and Tritonidae. The striking difference . . . is the absence

⁴⁰ Dickerson, Roy E., Note on the Faunal Zones of the Tejon Group, Univ. Calif. Publ. Bull. Dept. Geol. vol. 8, p. 17-25, 1914.

of such forms as *Trochocyathus striatus* . . . and *Schizaster lecontei* . . . and of glauconite. In both of these faunas two of the commonest Tejon species, *Turritella uvasana* and *Amauropsis alveata*, are missing. The fauna of South Table Mountain Eocene is merely a different facies than that of the Marysville Buttes and the absence of the coral, echinoderm, and glauconite mentioned above is due to differences in bathymetric conditions. The South Table Mountain Eocene was deposited under littoral conditions, while that of the Marysville Buttes was deposited in considerably deeper water. The differences in lithology confirm this conclusion. These faunas are approximately the same age, but deposited under quite different conditions.

The evidence stated above demonstrates the Eocene age of the sediments beneath the Older Basalt, correlates these beds with the *Siphonalia sutterensis* zone of the Marysville Buttes region and shows their direct connection with the stream-laid deposits of the Sierra Nevada. That the strata beneath the Older Basalt are identical with the Ione at its type locality in Amador County will be evident after its description.

THE IONE AT ITS TYPE LOCALITY.

LOCATION

The Ione formation from Oroville southward along the eastern edge of the Great Valley exhibits many of the same characteristics as were described at Oroville. A low westerly dip and an intimate association with the Bench Gravels and the Deep Gravels of Lindgren and rhyolitic tuff of the Sierra Nevada are common to the Ione from Oroville south to the vicinity of Fresno. The type locality of the Ione is in the vicinity of the town of that name in Amador County, California. The description of the type locality is given below.

TURNER'S DESCRIPTION OF THE TYPE SECTION

Turner⁵⁰ recognized three lithologic members in this formation: (1) the lower portion, a white clay; resting upon this (2) white or red sandstone; and then (3) a light-gray clay rock. (See plate 44, figs. 1 and 2.) He described it as follows:

Along the western border of the metamorphic rocks is a series of nearly horizontally stratified, light-colored sediments, which were deposited in the waters that covered the Great Valley at the time the older auiferous gravels with interbedded pipe-clays accumulated in the river beds of the Sierra slope. This formation attains its maximum development in the area of the Jackson Sheet. The lower portion of the series, composed largely of

⁵⁰ Turner, H. W., Jackson Folio No. 11, California, U. S. Geol. Surv., p. 2, 1894.

white clay, is well exposed around Ione, whence the formation takes its name. Farther south the white clays are overlain by sandstone, above which is a fine-grained clay rock. The lower, white clay is in places quite free from grit and is used in making pottery. Other portions are sandy. The formation contains iron-ore and coal seams. The sandstone is used for building purposes. It is usually white, but at one quarry a brick-red variety, colored by finely disseminated hematite, is obtained. At other localities it is rusty and contains pebbles of white quartz, passing into a conglomerate. A peculiar hydrous silicate of alumina occurs abundantly in the sandstone in the form of cream-colored, pearly scales.

The clay rock occurring above the sandstone is light-gray—but usually more or less discolored. The fracture is, as a rule, irregular, and the rock frequently contains minute, tubular passages. Under the microscope it is seen to be composed of fine particles of feldspar and fine discolored sediment, with occasional quartz grains. Analyses of two specimens gave 59 and 72 per cent silica and 4.8 and 1.6 per cent of alkali.

The succession of white clay, sandstone and clay rock may not be constant throughout the entire area mapped as belonging to the Ione formation. It has been suggested that the white clay of the lower beds was formed from rhyolitic tuffs, in which case eruptions of rhyolite must have occurred at the beginning of the Ione epoch.

The thickness of the Ione formation is known partly by natural exposures, partly by boring. In Jones Butte the strata, protected from erosion by a lava cap, are 200 feet thick above Coal Mine No. 3. A boring at the mine is said to have penetrated sandy clay to a depth of 800 feet below the coal seam, which is 60 to 70 feet below the surface. Thus the Ione beds appear to be more than 1000 feet thick at this point (see fig. 5).

To the east of Buena Vista Peak the series has a visible thickness of 600 feet. The table-land south and southwest of Buena Vista is chiefly composed of the Ione formation, overlain by rhyolitic and andesitic tuff and Neocene shore gravels. The lower clay occurs at the east base of the table-land, and a patch of Ione sandstone caps Waters Peak, a little farther east, which has an elevation of about 900 feet.

The relation of the sandstone to the clay rock is finely exposed on the south side of the Mokelumne River, by the bridge north of Camanche. Here the sandstone forms the lower part of the bank of the river. The upper surface of the sandstone has a gentle westerly dip, and a little west of the bridge reaches the level of the river, which at this point is about 175 feet above sea-level. East of the bridge it rises at an angle of about 1°, reaching an altitude of 1000 feet on the flat ridge just north of Valley Springs Peak. Along the banks of the Mokelumne west of Lancha Plana this sandstone attains a thickness of more than 100 feet.

Turner, in describing the Neocene shore gravels, states their relationship to the Ione as follows:

The most striking evidence of nonconformity, however, may be seen at the red sandstone quarry three miles southeast of Buena Vista. Here the Neocene shore gravels rest unconformably on the smooth waterworn surface of the sandstone, which is red where quarried, but white at the northern end of the exposure. Waterworn bowlders of the white sandstone may be seen in the gravel. Southwest of the quarry the ridge is

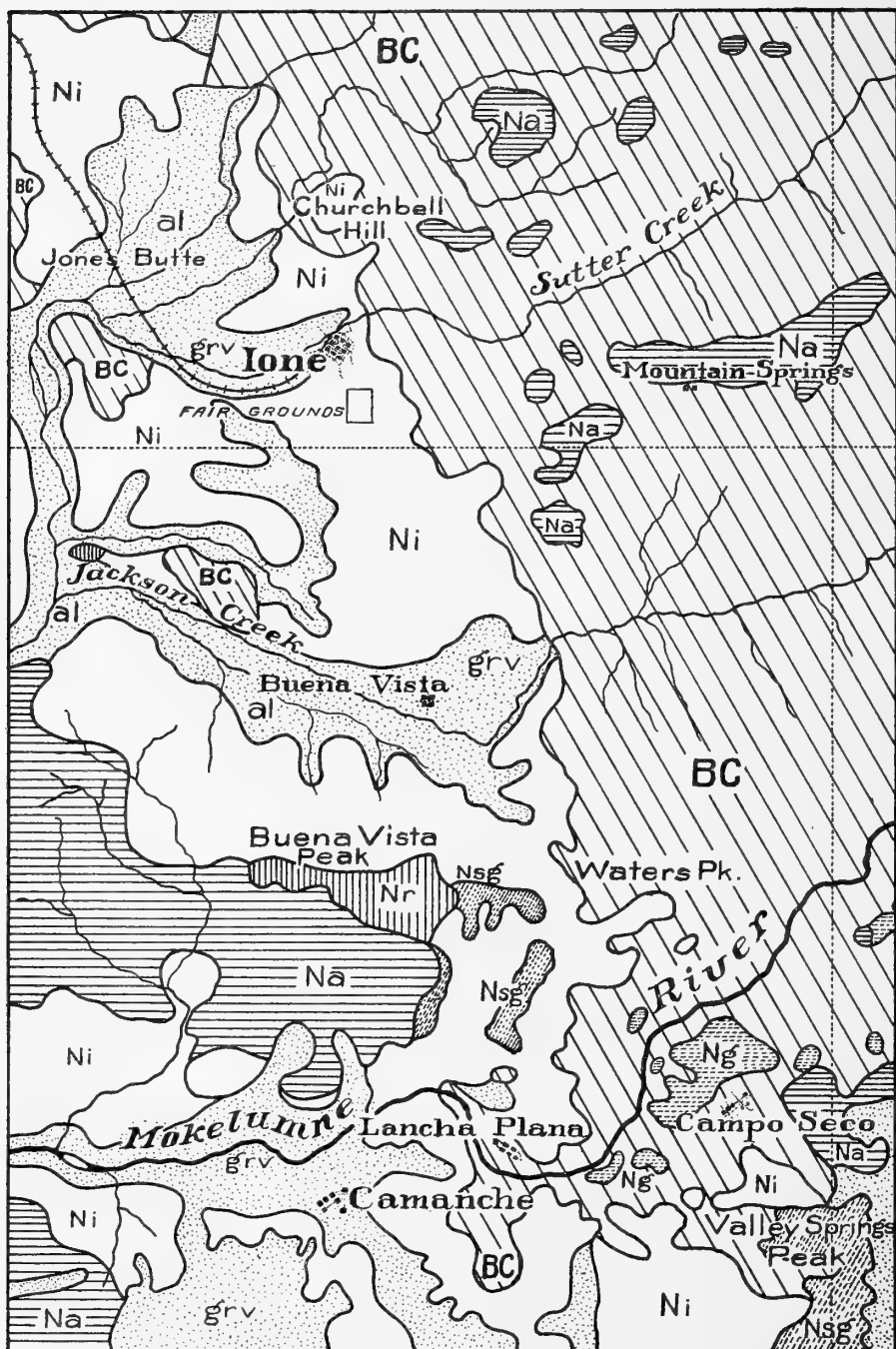


Fig 5. Geological Map of a portion of the Jackson Quadrangle. Adapted from the Jackson Folio. Scale, $\frac{1}{2}$ inch—1 mile.

BC, Basement Complex; ng, Auriferous Gravels; ni, Ione Formation; nsg, Neocene shore gravels; na, andesitic tuffs; grv, Pleistocene shore gravels; al, alluvium.

capped for a distance of more than a mile with the same gravel, which half a mile from the quarry contains a layer of *andesitic* detritus. At the extreme southwestern end of the ridge is a body of similar gravel, which also rests plainly on sandstone of the Ione formation.

OCCURRENCE OF EOCENE FOSSILS IN THE IONE

All the localities described by Turner have been visited. At the last-mentioned locality, "the red sandstone quarry three miles south-east of Buena Vista," the writer obtained *Venericardia planicosta merriami*, *Meretrix hornii* Gabb, *Psammobia*, cf. *hornii* Gabb, *Crassatellites*, sp., *Turritella merriami* Dickerson, *Natica*, sp., and *Clavella*, sp. The *Venericardia planicosta* found here is the variety with the obsolete ribs. All of these forms were collected from the sandstone five to ten feet beneath the Neocene shore gravels. While the fauna is a small one, it is typical of the uppermost, the *Siphonalia sutterensis* zone of the Tejon. The sandstone member in this vicinity with a dip of only one degree toward the west attains a thickness of 250 feet. It rests upon the clay, an altered rhyolitic tuff which is only fifty to one hundred feet in thickness. This in turn rests upon the steeply tilted eastward-dipping Mariposa slates of the bedrock series. The same sandstone occurs on the hill east of Buena Vista Peak, and with about the same thickness. A half mile east of the hill the lower clay member becomes appreciably thinner and is only twenty-five to fifty feet thick. On Waters Peak, one-half mile farther east, the clay member and a good part of the sandstone member are missing and only the massive upper fifty feet of the sandstone member is found resting upon the eroded surface of the Mariposa slates.

The third member, the clay rock recognized by Turner, appears to the writer to be merely a decomposition product of a rhyolitic tuff. This rhyolitic tuff rests directly upon the sandstone member in the vicinity of Buena Vista Peak. This is confirmed by an examination of the strata as exposed in Jones' Butte. A clay rock was found resting upon the sandstone member. In certain places this rock was found to be an unaltered rhyolitic tuff.

From the above description it is seen that this formation appears to have been deposited by a sea which transgressed from the west. Two or more of the three members of the Ione are very persistent over the Jackson Quadrangle, the Lodi Quadrangle, the Sacramento Quadrangle, and the Sonora Quadrangle and they can be readily recognized by their lithologic characters, low westerly dip, and stratigraphic position beneath the andesitic tuffs and upon the Mariposa slates or other members of the bedrock series.

RELATION OF THE AURIFEROUS GRAVELS TO THE IONE FORMATION

Essentially the same relations as were found at Oroville⁵¹ exist between the Auriferous Gravels in the vicinity of Ione and the Ione formation. Along the Calaveras River three miles east of Stone Corral the intimate relationship of the Auriferous Gravels to the Ione is shown by the mapping in the Jackson Folio. Both rest directly upon the diabase of the basement complex and they are only a quarter of a mile apart in one locality. The mapping in the vicinity of Campo Seco shows a direct relation between the marine Ione and the gravels. The Ione area at Mule Town two miles north of Ione has all the characteristics of the Auriferous Gravels and might have been mapped as such but for its evident close association with the Ione a short distance further west. A direct connection seems to exist between the marine Ione and the stream deposits of the Sierra Nevada. Probably short consequent high-grade streams emptied into the Eocene embayment now represented by the lower member of the Ione. Apparently the shore line passed through the present sites of the towns of Ione, Buena Vista, and Valley Springs.

These facts show that the Ione is the marine or estuarine equivalent of the Auriferous Gravels, stream-laid deposits of the Sierra Nevada.

THE IONE FORMATION NEAR MERCED FALLS

Until these three members were studied at the type locality, the relationship of the small area south of Merced Falls, which was mapped by Ransome and Turner as Tejon, to the adjoining Ione tuffs and clays was obscure. The clays, sands and tuffs exposed one mile west of Merced are lithologically identical with those of the lowermost member, and the red sandstone mapped as Tejon found here is identical with that of the second or sandstone member of the Ione of the type locality. The same condition evidently prevailed here as in the area between Waters Peak and Buena Vista Peak, that is, a deposition along the shore line of a rapidly transgressing western sea. In this sandstone, casts of the *Venericardia planicosta merriami* were found near the top. The authors of the Sonora Folio, Messrs. Turner and Ransome,⁵² described this as follows:

⁵¹ Dickerson, R. E., Note on the Faunal Zones of the Tejon Group, Univ. Calif. Publ. Bull. Dept. Geol., vol. 8, p. 23, 1914.

⁵² Turner, H. W., and Ransome, F. L. Sonora Folio, U. S. Geological Survey, p. 2, 1897.

Tejon formation.—The only rocks referable to this period are a few isolated patches of light-colored sandstone which occur capping some low hills in the southwest corner of the quadrangle. South and southeast of Merced Falls are two level-topped buttes capped by this sandstone, which rests almost horizontally upon the nearly vertical edges of the Mariposa slates. The basal bed is crowded with angular fragments of the slate and with abundant pebbles of white vein quartz, while the upper beds are composed of a light-colored quartzose sandstone with frequent bands of small quartz pebbles. Marine fossils (*Venericardia planicosta*) are fairly abundant in the upper bed at the west end of the butte that lies one mile south of Merced Falls. These sandstones are overlain to the west by the light-colored sandstones of the Ione formation. The two series are probably not absolutely conformable, as the Ione beds transgress onto the rocks of the bedrock series farther north.

The above-mentioned sandstones, instead of "being overlain to the west by the light-colored sandstones of the Ione formation," are in reality stratigraphically higher. These sandstones have been worn away from most of this area and only a few residuals remain.

After this great erosion, andesitic tuffs and tuff breccias covered all. During the Pleistocene and Recent time much of the andesitic material has been removed, re-exposing the older rocks beneath.

THE IONE FORMATION IN THE VICINITY OF BEAR CREEK, MERCED COUNTY

The region south of Merced Falls was first described by Blake⁵³ in the Pacific Railroad Reports. The exploration route was along the old Fort Miller road from Merced Falls to Fort Miller. Blake recognized the unconformity between the sandstone and the underlying slates and he figured two hills showing the characteristic topography yielded by the middle member of the Ione.

His description of the country south of the Merced is as follows:

Merced river to Bear Creek, July 22, 18.3 miles.—After leaving the Merced our route lay among numerous isolated hills with flat summits; a group of which is represented in outline in the figure. These hills were estimated to be about one hundred feet in height. They are formed of horizontal strata, and are the remnants of a former plain, the intermediate portions having been removed by denudation. The "cap rock" on one of the hills was found to consist of a bed of conglomerate, chiefly of quartz pebbles, underlaid by a bed of light-colored sandstone, and a second stratum of conglomerate. A cylindrical object, like a log of wood, was protruding two feet beyond this layer of sandstone, and it proved to be a part of a fossil tree, with a cross-section like the figure.

It was somewhat flattened as if by pressure. Its outer portions had evidently been bored into by worms, as cavities similar to those formed

⁵³ Blake, W. P., Explorations and Surveys for a Railroad Route from the Mississippi River to the Pacific Ocean, vol. 5, part 2, pp. 12-15, 1853.

by the Teredo were found filled in with sandstone. The whole mass was highly charged with Peroxide of iron, which, indeed seemed to be the chief constituent.

We had now progressed so far toward the mountains that we were no longer upon the broad plains of the great valley of the San Joaquin, but were traveling along the foot-hills of the Sierra Nevada. Our route from this point, southward to Fort Miller, lay nearly on the border of the lower granitic ranges, which presented occasional opportunities for examining them, in connexion with the sedimentary foot-hills.

The first outcrop of any of the rocks of the granitic and metamorphic series met on the survey was near Howard's ferry on the Merced. At that place extended outcrops of dark-colored clay slate were observed, having a trend N 55° W, and an inclination of 70° toward the east. In some places they appeared chloritic; and in others had the general character of roofing slate. They were traversed in the direction of the bedding, by quartz veins of great thickness, the white quartz contrasting finely with the black slate. This place is only nine miles west from Quartzburg, where several mining companies have erected crushers and stamps for pulverizing the quartz and extracting the gold it bears. The unconformability of the sedimentary sandstone formation with these roofing and chlorite slates is strikingly shown in this vicinity, where streams have cut so deeply as to expose both formations. The horizontal strata rest upon the upturned edges of the slates, as is shown in the section.

The outcropping layers of hard sandstone were visible in the hills on each side, the intermediate portion (between the hills) having been removed by denudation. At the highest part of the outcrop of slates, a quartz vein, five feet thick, stands out above the general surface, and forms a wall-like mass of fragments. These being milk-white, contrast strongly with the black slate on each side. This quartz has preserved the surrounding slate from abrasion by currents of water, and thus it stands at the summit of a little eminence.

Burns' Creek.—A remnant of the former elevated plain of sandstone formed a picturesque object near our route, and was sketched by Mr. Koppel. It consists of a nearly circular disk of compact sandstone, ten or fifteen feet thick, capping the summit of a round mound. Hills of this character, of greater extent and elevation, are numerous for several miles south of this point.

Bear Creek.—At Bear Creek twelve miles north of the Mariposa river, a good natural section or vertical exposure of the strata composing one of these flat-topped hills was presented. It consisted of a series of beds of coarse and fine sandstone and strata of gravel and conglomerate, which are represented in section, Chapter XIII. The whole elevation of the hill was estimated to be about 150 feet. The following is the succession of the strata as observed from the top downwards to the level of the creek. The thicknesses are given as they were estimated, and are therefore, merely approximate. The letters refer to the section.

Section of the Strata at Bear Creek

k. Conglomerate.....	6 feet
j. Sandstone.....	50 "
i. Conglomerate.....	22 "
h. Sandstone, fine.....	1 "

g. Conglomerate of gravel, white and black quartz, and nodules of carbonate of lime.....	10 feet
f. Sandstone, showing diagonal stratification and one or two layers of gravel	12 "
e. Sandstone, with a layer of pebbles.....	3 "
d. Hard sandstone, thinly bedded; layers of pebbles towards the base.....	20 "
c. Compact sandstone, with some small pebbles.....	2 "
b. Sandstone, with coarse grains and pebbles.....	1 "
a. Sandstone	

The upper stratum is perfectly level on the top and free from soil; a dwarfed bush or tree, here and there, is the only vegetation. The whole surface appears fissured, or as if cracked by drying in the sun—precisely as the soil is cracked during the dry season. This must have taken place at the time of the deposition of the rock or soon after. On closely inspecting the slight accumulations of fine gravel in some of the hollows of the rocks, numerous very small but beautiful crystals of andalusite were found. These did not exceed three-sixteenths of an inch in diameter, and were seldom over one-eighth. They are translucent, but appear to be worn and rounded by attrition.

Turner⁵⁴ described these as a continuation of the same formations found one mile south of Merced Falls. He described the igneous rocks of this neighborhood as follows:

Along the east side of the valley to the south of the Merced River is a plateau, the upper layers of which, where examined, are composed of andesitic detritus mixed with ordinary sand. Some of the white underlying material may be of rhyolitic origin. At any rate the white material at the edge of the plains just west of Daultons in Madera County is rhyolite.

The region in the vicinity of Bear Creek was recently visited by Mr. Chester Stock and the writer for the Department of Palaeontology of the University of California to search for remains of *Auchenia californica*⁵⁵ Leidy and other Tertiary mammals which

⁵⁴ Turner, H. W., *Geology of Sierra Nevada*, Seventeenth Annual Report, U. S. Geological Survey, part I, p. 683, 1896.

⁵⁵ The various beds described above were searched thoroughly for marine and land remains, but none were found. A point six miles southwest of Indian Gulch on the Mariposa line would be at Burns Creek. How Whitney could describe Burns Creek as a nameless tributary of Bear Creek is hard to understand, because this creek is distinctly mentioned in the Pacific Railway Report and was early known by that name. Leidy's statement concerning the label which accompanied *A. californica* is that the specimen was found beneath the basalts at Table Mountain near Shaw's Flat, Tuolumne County, California. C. D. Voy who collected the specimen of *A. californica* may have collected *Venericardia planicosta merriami* Dickerson at the locality six miles southwest of Indian Gulch.

In the *Geology of the Sierra Nevada* (17th Annual Report, p. 683) Turner states:

"In a paper on the auriferous gravels attention was called to an interesting locality of vertebrate remains described by Professor Whitney as being on a dry creek tributary to Bear Creek near the line of Mariposa and Merced Counties. A search was made for this locality but no evidence of such remains was found. Professor Whitney later informed the writer that he himself had investigated the locality and had been unable to find it."

were supposed to occur in this vicinity, according to Whitney. The following notes were made incidentally.

The rocks recognized in the area are: (1) The Basement Complex, the bedrock series; (2) The Ione Eocene of the superjacent series; (3) Pleistocene (?) shore gravels (of Turner).

The basement complex consists of slates of probable Mariposa age, amphibolite schists and associated granitoid rocks. The latter rocks are well exposed in Burns Creek at the county line. Schists and slates are in general found in the area northeast of the old Fort Miller road, along which Blake and the other geologists of the Pacific Railroad expedition journeyed. Several points in their description were easily recognized, particularly a small butte capped by Ione sandstone in the vicinity of Burns Creek, and figured in the Pacific Railroad report. The slates and schists form an extensive belt.

The middle or sandstone member of the Ione rests unconformably on the slates and schists. It varies in thickness from 25 to 75 feet in various portions of the field. Evidences of deposition along the immediate shoreline were found. Distinct mud-cracks were seen in the sandstone blocks on top of the butte northwest of the mouth of Bear Creek Cañon. The relations between the middle sandstone member and the lower rhyolitic tuff member were well shown in an east-west section along Burns Creek near the county line. (See figure 6. An eighth-mile south of the county line the middle

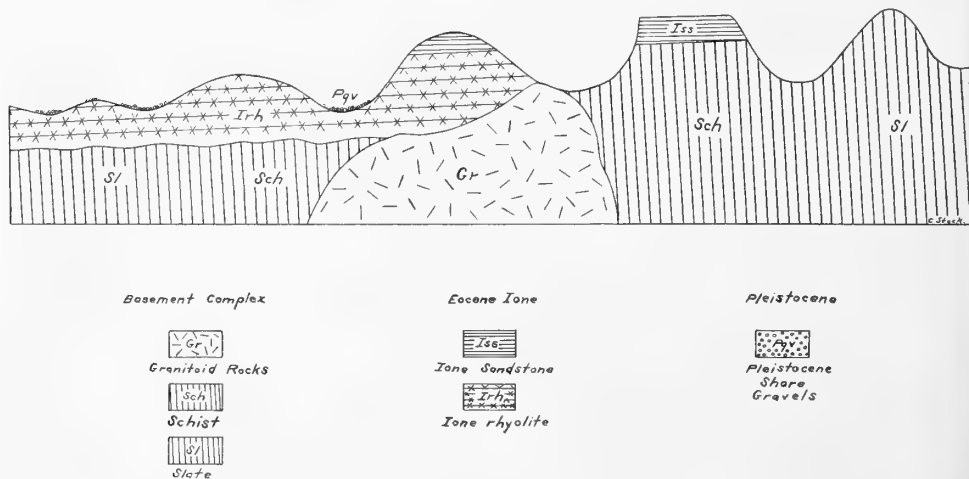


Fig. 6. Generalized section in vicinity of Burns Creek, showing relations between Ione members and the bedrock series. (Drawn by Chester Stock.)

member rests directly upon the basement complex. An eighth of a mile west of the county line the middle member rests upon the lower member which consists of rhyolitic tuff. The accompanying section shows this relation graphically.

The lower member is characteristically tuffaceous, although distinct beds of gravel occur within it. There are several lithologic facies exhibited in this member, as follows:

(1) A fine-grained kaolinized ash.

(2) Red-brown tuff-breccia weathering to a red, which occasionally contains partially altered fragments of rhyolite.

(3) A conglomerate which consists of quartzose pebbles, schist and slate fragments, along with a few rhyolitic pebbles, the whole being in a rhyolitic ash matrix. This member has a low westward dip throughout the field of three to four degrees, and apparently underlies most of the valley border for a distance of six miles from the old Fort Miller Road. This member is exposed in the lower course of Burns Creek.

DEEP-WATER EQUIVALENT OF THE IONE AT MARYSVILLE BUTTES STRATIGRAPHY

After a study of the Ione along the foothills of the Sierra Nevada the writer recently made another brief visit to the Marysville Buttes to study the Ione as mapped in the Marysville Folio.^{55a}

The occurrence of Eocene strata in the vicinity of the Marysville Buttes⁵⁶ has been described at length in a previous paper.

The stratigraphic relations were described as follows (p. 261):

In general, the sedimentary beds dip away from the central core. The only Eocene area which is mapped in the Marysville folio is a strip about a mile and a quarter long by a quarter mile wide on the west side of the buttes two miles east of South Butte. The Eocene in this area is overlain by the Ione formation which has a dip of 15° W, while the Eocene has in most places a dip of 35° to 40° W, strike N 90° W, although the dip is nearly vertical near West Butte Peak. The Ione consists of gravels and sands, for the most part unconsolidated. Cross-bedding is very common and intricate. These sediments were probably deposited on the Eocene as an alluvial fan. The Ione in turn is overlain by andesitic mud flows—now firmly cemented—which dip to the west about 4° to 5°.

An east-west section through West Butte largely adapted from the Marysville Folio shows the following sequence on the west side:

^{55a} Lindgren, W., and Turner, H. W., Marysville Folio, U. S. Geological Survey, Folio 17, 1895.

⁵⁶ Dickerson, R. E., Fauna of the Eocene at Marysville Buttes, California, Univ. Calif. Publ. Bull. Dept. Geol., vol. 7, pp. 257-298, 1913.

100 feet of green-gray sandstone and shale with limestone concretions marking the upper limit of the Eocene.

300 feet of green-gray, glauconitic shale.

200 feet of massive, thin-bedded, buff sandstone.

100 feet of impure, gray limestone with thin strata of hard gray, medium-grained sandstone.

600 feet of massive, medium-grained, yellow, non-fossiliferous sandstone in contact with the andesitic core.

Resting upon the Eocene are 500-600 feet of Ione gravels and sands. The two uppermost Eocene members, which are very fossiliferous, can be easily recognized in the field by the bright red, clay soil formed through their decay. The limestone concretions which are sometimes yellow, contain many small, dark green to black, rounded grains. When these are carefully examined with a hand lens they are found to be foraminiferal casts composed of glauconite. The green shales as well as the sandstone also contain glauconite and foraminifers. The strata are lithologically similar to certain horizons in the Martinez, but the character of the fauna here compels us to abandon the notion that green glauconitic sandstone and shale are absolutely indicative of the Martinez in the middle California region. Glauconitic sandstone also occurs in the Tejon of the Mount Diablo region.

On the east side of the South Butte the writer has mapped another Eocene area which has about the same sequence as the above. Thin strata of coal are reported by Watts and later by Lindgren and Turner, from the lower portion of this section.

According to H. Hannibal some of the area south of South Butte mapped as Ione is Cretaceous.

In the section given above the "100 feet of impure gray limestone with thin strata of hard gray, medium-grained sandstone" is probably the upper member of the Chico Cretaceous, as fossils *Spisula ashburneri* (Gabb), *Trigonia evansana* Meek and *Gyrodes expansa* Gabb were found in a stratum of sandstone at its base. The "600 feet of massive . . . sandstone" is also Chico Cretaceous.

DESCRIPTION OF THE SUTTER FORMATION

Resting with marked unconformity upon the Chico and the Tejon are 500-600 feet of strata which are composed chiefly of rhyolitic ash, rhyolitic tuff-breccia, thin flows of rhyolite and conglomerate containing rhyolitic and quartz pebbles. This formation is overlain by lava flows and mud flows which consist of andesitic material. Evidence of a time-interval between these two volcanic formations is given by a marked difference of dip between them throughout the field. The materials in the Sutter formation were derived chiefly from the rhyolitic volcanic rocks (mapped by Lindgren as Nr), as the lava composing the thin flow noted above

is identical with this rhyolite and some of the boulders in the conglomerate are likewise composed of this rock. The rhyolite areas mapped are in close association with the Sutter formation as a rule.

One of the best exposures for study is seen on a ridge one mile southwest of West Butte. The beds at this place cap the underlying Cretaceous. The overlying beds dip 10° W, while the underlying Chico strata dip 40° W. The strata are composed chiefly of what appears to be a much altered rhyolitic tuff-breccia which looks at first sight to be a sandstone. This rock is light gray when weathered and a dark gray on unweathered surfaces. It is composed of very angular quartz grains, altered biotite and feldspar. Gypsum commonly fills the joint planes and in places occurs between the bedding planes. Lenses of conglomerate occur interbedded with this rock and two thin flows of igneous rock four to eight inches in thickness were also noted.

Farther west on this same ridge, this formation is found in fault contact with the Tejon at the top of a small divide crossed by the county road. This divide is located one and a half miles S 50° W of West Butte. The Sutter formation at this point has a dip of 22° W and a strike of N 20° W. The beds vary locally, cross-bedding being common. Besides the rocks described above, a light-gray tuff composed of fine ash particles occurs here. The andesite is sharply separated from the Sutter formation at this locality and it has a dip of only 6° W. This same relation is seen in the 547-foot hill one mile north. Similar relations between the Sutter and the underlying and overlying formations were found south of South Butte. This formation is named for its occurrence in Sutter County, California, in what is now known as the Marysville Buttes (formerly Sutter Buttes).

HISTORICAL GEOLOGY

The sequence of events which gave us the Marysville Buttes in their present form appears to be as follows:

(1) The lowering of the continental margin and the deposition of Chico Cretaceous strata by a transgressing sea from the west; (2) a great time-interval during which this site was land; (3) submergence at the end of Tejon time which resulted in the deposition upon the outer edge of the continental shelf of Eocene strata composed of foraminiferal shales, the deep-water equivalents of the in-shore Ione of the Sierran foothills; (4) uplift; (5) an intrusion of

rhyolite and consequent upturning and faulting of Cretaceous and Eocene strata and outpouring of rhyolitic flows and ash deposits (the Sutter formation) upon these faulted and folded sedimentaries; (6) a period of erosion during which a large portion of the Sutter formation was removed; (7) an intrusion into these older formations mentioned above and outpouring of andesitic materials from a great central volcano; (8) a long erosion interval during which short streams consequent upon the lava slope cut through the andesitic lava into the softer underlying deposits. Of these deposits the softest is the Sutter. The pass between the towns of West Butte and Sutter City was cut in this material. The "secondary craters" described in the Marysville Buttes Folio appear to be erosion valleys formed in the Sutter formation by subsequent tributaries of consequent streams.

In conclusion, there does not appear to be any formation in the Marysville Buttes except the Tejon Eocene strata which could possibly be the equivalent of the Ione of the Sierran foothills. It has been shown above that these Eocene strata are the off-shore equivalents of the inshore Ione.

SUMMARY OF FAUNA OF THE SIPHONALIA SUTTERENSIS ZONE

The discovery of several new areas in which the *Siphonalia sutterensis* zone was represented and large additions to the faunas modify the previous conclusions of the writer concerning this zone. Many of the forms which were thought to be characteristic have been found at lower horizons and several more species characteristic of the middle and lower portions of the Tejon group are now reported from this zone. The list of species obtained from this zone is given below.

LIST OF SPECIES FROM LOCALITIES IN THE SIPHONALIA SUTTERENSIS ZONE

	1853	1856	692	2225	2365
<i>Nodosaria</i> , sp.	×
<i>Balanophyllia variabilis</i> Nomland	×	×
Coral, sp. a.	×
<i>Flabellum</i> , sp.	✓
<i>Stephanophyllia californica</i> Nomland.....	×
<i>Trochocyathus</i> (?) <i>perrini</i> Dickerson.....	×
<i>Schizaster lecontei</i> Merriam	×
<i>Acila gabbiana</i> , n. sp.	×	×	×
<i>Arca hornii</i> Gabb	×	×
<i>Avicula pellucida</i> Gabb	×

LIST OF SPECIES FROM LOCALITIES IN THE SIPHONALIA SUTTERENSIS ZONE—
(Continued)

	1853	1856	692	2225	2365
<i>Barbatia morsei</i> Gabb	×
<i>Barbatia</i> , sp. a.	×
<i>Cardium marysvillensis</i> Dickerson.....	×	×	×
<i>Corbula parilis</i> Gabb	×	×
<i>Corbula hornii</i> Gabb	<
<i>Crassatellites</i> , sp.	<
<i>Crassatellites grandis</i> (Gabb)	×	×
<i>Diplodonta polita</i> (Gabb)	×
<i>Dosinia elevata</i> Gabb	×
<i>Glycimeris cor</i> Gabb	×
<i>Glycimeris marysvillensis</i> Dickerson.....	×
<i>Isocardium tejonensis</i> Waring	×
<i>Leda gabbi</i> Conrad	<	×
<i>Macrocallista conradiana</i> (Gabb)	✓
<i>Meretrix</i> (?), sp.	<
<i>Meretrix ovalis</i> Gabb	×	×
<i>Meretrix hornii</i> Gabb	×	×	×	✓
<i>Modiolus ornatus</i> (Gabb)	×
<i>Nucula cooperi</i> Dickerson	×
<i>Ostrea aviculaformis</i> Anderson	<
<i>Ostrea</i> cf. <i>appressa</i> Gabb	×
<i>Placunanomia inornata</i> Gabb	×
<i>Phacoides cretacea</i> (Gabb)	×
<i>Pecten</i> , sp.	×	×
<i>Psammobia hornii</i> (Gabb)	×	×	×
<i>Spisula merriami</i> Packard.....	×
<i>Solen parallelus</i> Gabb	×	×	×
<i>Tellina sutterensis</i> Dickerson	×	×
<i>Tellinga longa</i> Gabb	×
<i>Teredo</i> , sp.	×
<i>Venericardia planicosta merriami</i> Dickerson....	×	×	×	×
<i>Venericardia</i> , sp.	×
<i>Cadulus pusillus</i> (Gabb)	×
<i>Dentalium stramineum</i> Gabb	×	×
<i>Ancilla</i> (Oliverato) <i>californica</i> Cooper.....	×	×
<i>Astyris</i> , sp.	×
<i>Architectonica weaveri</i> Dickerson	✓
<i>Architectonica ullreyana</i> , n. sp.	×
<i>Acmaea ruckmani</i> , n. sp.	×
<i>Bittium featherensis</i> , n. sp.	×
<i>Bittium longissimum</i> Cooper	×
<i>Bullaria hornii</i> (Gabb)	×
<i>Cancellaria irelaniana</i> Cooper	×
<i>Cancellaria stantoni</i> Dickerson	×	×
<i>Calyptrea excentrica</i> (Gabb)	×	×	×
<i>Caricella stormsiana</i> Dickerson	✓	×
<i>Calliostoma arnoldi</i> Dickerson	×
<i>Cerithiopsis orovillensis</i> , n. sp.	×
<i>Chrysodomus martini</i> Dickerson	×	×

LIST OF SPECIES FROM LOCALITIES IN THE SIPHONALIA SUTTERENSIS ZONE—
(Continued)

	1853	1856	692	2225	2365
<i>Clavella tabulata</i> Dickerson.....	x	---	---	---	---
<i>Cordiera gracillima</i> Cooper	x	x	---	x	---
<i>Cylichna costata</i> Gabb	x	---	x	---	---
<i>Drillia ullreyana</i> Cooper	x	---	---	x	---
<i>Drillia cooperi</i> , n. sp.	x	---	---	---	---
<i>Drillia orovillensis</i> , n. sp.	---	---	---	x	---
<i>Exilia perkinsiana</i> (Cooper)	x	---	---	x	---
<i>Exilia dickersoni</i> (Weaver)	---	---	---	x	---
<i>Fusinus lineatus</i> Dickerson	x	---	---	---	---
<i>Fusinus merriami</i> , n. sp.	x	---	---	---	---
<i>Ficopsis remondii</i> Gabb	x	---	---	---	---
<i>Galeodea tuberculata</i> (Gabb)	x	---	---	---	---
<i>Lunatia nuciformis</i> Gabb	x	x	---	x	---
<i>Monodonta wattsi</i> , n. sp.	x	---	---	x	---
<i>Murex</i> (<i>Ocenebra</i>) <i>nashi</i> , n. sp.	---	---	---	x	---
<i>Natica</i> , sp.	---	---	---	---	x
<i>Nyctilochus diegoensis</i> (Gabb)	---	---	---	x	---
<i>Nyctilochus thunani</i> , n. sp.	---	---	---	x	---
<i>Nyctilochus californicus</i> Gabb	x	x	---	---	---
<i>Nyctilochus whitneyi</i> Gabb	x	x	---	---	---
<i>Niso polita</i> Gabb	x	---	---	---	---
<i>Neverita globosa</i> Gabb	x	---	---	x	---
<i>Neverita secta</i> Gabb	x	---	---	x	---
<i>Olivula marysvillensis</i> Dickerson	x	---	---	---	---
<i>Olivella mathewsonii</i> Gabb	x	---	x	---	---
<i>Perissolax blakei</i> (Conrad)	x	---	---	---	---
<i>Surcula crenatospira</i> Cooper	x	---	---	---	---
<i>Surcula holwayi</i> Dickerson	x	---	---	---	---
<i>Surcula clarki</i> Dickerson	x	---	---	x	---
<i>Surcula davisiana</i> (Cooper)	x	---	---	---	---
<i>Surcula</i> (<i>Surculites</i>) <i>sinuata</i> Gabb.....	x	---	---	---	---
<i>Siphonalia sutterensis</i> Dickerson	x	---	---	x	---
<i>Terebra wattiana</i> Cooper	x	---	---	---	---
<i>Turritella</i> , sp.	---	---	x	---	---
<i>Turritella merriami</i> Dickerson.....	x	---	x	x	x
<i>Turris andersoni</i> Dickerson	x	---	---	---	---
<i>Turris inconstans</i> Cooper	x	---	---	x	---
<i>Turris monolifera</i> Cooper.....	x	x	---	x	---
<i>Turris suturalis</i> (Cooper).....	x	x	---	---	---
<i>Voluta lawsoni</i> Dickerson	x	x	---	---	---
<i>Cancer</i> , sp.	x	---	---	---	---
<i>Synechodus</i> , sp.	x	---	---	---	---

LIST OF LOCALITIES

1853. Marysville Quadrangle. Tejon Group. About two and one-half miles west, ten degrees north of South Butte in small cañon east of county road. Coll., R. E. Dickerson.

1856. Marysville Quadrangle. Tejon Group. Two miles east of South Butte. Coll., R. E. Dickerson.

692. Marysville Quadrangle. Tejon Group. Two and one-eighth miles east, ten degrees south of South Butte. Coll., C. K. Studley.

2225. Chico Quadrangle. Tejon Group. Two miles north of Oroville in the Dyer mining shaft. Colls., J. Ruckman and R. E. Dickerson.

2365. Jackson Quadrangle. Tejon Group. Red sandstone quarry three miles southeast of Buena Vista. Coll., R. E. Dickerson.

2067. Sonora Quadrangle. Tejon Group. One mile south of Merced Falls on top of a low hill, "Planicosta Butte". Coll., R. E. Dickerson.

Of the species listed the following have not been reported at lower horizons in California:

Trochocyathus(?) perrini, *Barbatia*, sp. a., *Cardium marysvillensis(?)*, *Glycimeris marysvillensis*, *Venericardia planicosta merriami*, *Architectonica weaveri*, *Bittium longissimum*, *Caricella stormisiana*, *Cordia gracillima*, *Calliostoma(?) arnoldi*, *Galeodea sutterensis*, n. sp., *Fusinus lineatus*, *Olivula marysvillensis*, *Chrysodomus martini*, *Surcula crenatospira*, *Surcula holwayi*, *Surcula davisiana*, *Siphonalia sutterensis*, *Terebra wattsiana*, *Voluta lawsoni*, *Bittium featherensis*, n. sp., *Cerithiopsis orovillensis*, n. sp., *Drillia cooperi*, *Drillia orovillensis*, *Nyctilochus thunani*, n. sp., *Murex nashi*, n. sp.

A study of a littoral facies of the *Siphonalia sutterensis* fauna at Oroville, at locality 692, and at the mouth of Little River, North Fork of the Umpqua River in beds near the top of the Tejon group (Umpqua Formation), confirms and reinforces the writer's previous conclusion that "The unique character of the Marysville Buttes fauna appears to be due to its representing a period from which no adequate fauna had previously been obtained. . . . That it evolved from the typical Tejon there can be little doubt. . . . In other words, the evidence indicates that the Marysville Buttes fauna represents a later zone or stage of the Eocene than the typical Tejon." The faunal list given above demonstrates conclusively that the *Siphonalia sutterensis* fauna was evolved from the typical Tejon and that the fauna is in reality much closer to the Tejon than the writer suspected three years ago. On this account the fauna is placed as the uppermost zone of the Tejon group in California.

CORRELATION OF THE IONE AND THE AURIFEROUS GRAVELS

Various workers in Sierran geology, including Whitney, Turner, Diller, and Lindgren, have recognized a genetic relationship between the auriferous gravels and the Ione formation. Diller⁵⁷ says

⁵⁷ Diller, J. S., Topographic Revolution on the Pacific Coast, Fourteenth Annual Report, U. S. Geological Survey, Part II, p. 420, 1894.

that "On stratigraphic grounds the auriferous gravels are regarded as contemporaneous with the Ione formation of the Sacramento Valley, but here too as in the earlier auriferous gravels, the fossil plants and shells appear to indicate that they belong to the Miocene."

Lindgren⁵⁸ in his description of the Ione formation summarized conditions succinctly as follows:

During the Miocene period and contemporaneously with the accumulation of the later pre-volcanic gravels on the slopes of the Sierra Nevada, there was deposited in the gulf then occupying the Great Valley a sedimentary series of clays and sands to which the name Ione formation has been given. The water in this gulf was probably brackish; no marine fossils have been found in the Ione formation along the foot of the range, but fossil leaves, vegetable material, and in places, coal are abundant. At the mouth of the rivers which descended from the Tertiary Sierra Nevada extensive delta deposits were accumulated, and it is thus difficult in many places to draw any exact line between the Ione formation and the river gravels proper. The gravels in the formation are locally auriferous, though generally poor, because spread over large areas.

The lowest and oldest Tertiary auriferous gravels lie in troughs over which the Ione formation has transgressed, in places a depth of more than 500 feet. At many localities the sandstones and clays of the formation merge directly into the upper river gravels of the so-called benches. On the other hand, the thick gravels of the rhyolitic are distinctly later than the Ione formation. Turner has shown that in the Jackson Quadrangle extensive short or delta gravels of interhyolitic [these gravels are not interhyolitic but are andesitic, R. E. D.] age rest on the eroded surface of the Ione (see Pl. 11, B, p. 72).*

The Ione formation belongs to the Tertiary. The greatest thickness of the formation measured is in Calaveras County in the Jackson Quadrangle, where Turner has determined it to be about 1000 feet. Post-Ione erosion has removed the formation entirely over large areas.

The most northerly exposures of the Ione north of the Sierra Nevada, have been observed by Diller on Little Cow Creek and Pit River in the northwest corner of the Lassen Peak Quadrangle, Shasta County. The clays and sands are here directly overlain by andesitic tuffs and rest on metamorphosed slates of Jurassic or Triassic age at an elevation of about 2000 feet. South of this locality few exposures are seen until the Oroville Table Mountain is reached, a distance of nearly 100 miles. At this place, a capping of basalt, somewhat earlier than the andesitic flows, has preserved the Ione intact. The formation here consists of fine gravels, white clays and sands, and reaches to elevations of about 1200 feet. (See Pl. IV, B; fig. 4, p. 86; and fig. 5, p. 90.)* With insignificant exceptions, no further exposures occur between this point and Lincoln in Placer County, where some white clays are preserved underneath a capping of andesitic tuff in the midst of Quaternary gravels and a few miles west of the first outcrops of the pre-Cretaceous rocks, usually referred to by the collective name "Bedrock series".

About 40 miles northwest of Lincoln, in the late Tertiary andesitic

⁵⁸ Lindgren, W., Tertiary Gravels of the Sierra Nevada of California, Professional Paper, No. 73, U. S. Geological Survey, pp. 24 and 25, 1911.

*Lindgren's Plates.

volcano of Marysville Buttes, clays, sands and gravels of Miocene age have been brought up by the intrusion of igneous bodies and, although they are so much disturbed that the stratigraphic sequence can not be made out, there is strong probability that these strata should be identified with the Ione. They contain marine fossils associated with impressions of deciduous leaves, and the gravels contain some gold.

South of Lincoln the Ione formation is better exposed because it has been protected by andesitic tuff, but it does not reach a higher elevation than about 200 feet. South of American River the outcrops are more extensive, and the formation attains its greatest development in the foothills of Calaveras County. The lower part, consisting of white clay and sand, reaches a thickness of 860 feet or more and contains beds of lignite of poor quality. Above this rests a white sandstone which attains a thickness of 100 feet or more. A clay bed also of light color, 100 feet thick, overlies this sandstone. Near Valley Springs the Ione attains elevations of 1000 feet, and its highest members are probably several hundred feet above the deepest gravels of the Tertiary Calaveras River, which here debouches into the plains but which is not visible in this vicinity.

From all this it appears that during the later part of the prevolcanic gravel period the Ione formation transgressed along the whole front of the Sierra to a present elevation of somewhat more than 1000 feet. So far as can be judged from the present exposures, there has been little differential elevation along the front of the range since the time of the deposition of the formation. In other words, the fluctuations of the shore line are now indicated by horizontal lines at least between the Oroville Table Mountain and the foothills of Calaveras County.

The extent of the erosion which followed immediately after the deposition of the Ione formation along the foothills was greater than would be supposed from a study of the deposits in the rivers higher up in the range. The sequence is particularly well shown around the Oroville Table Mountain and in the foothills of Calaveras County. At the former place the andesitic tuffs (Tuscan tuff of Diller), which in Placer County appear to overlie the Ione formation conformably, are at least 500 feet below its top members. At the mouth of the old Yuba River there is a conspicuous absence of the Ione formation and the andesitic tuffs rest immediately on the bedrock, at elevations as low as 200 feet, and in the old river channel lie immediately above the heavy gravels which are presumably of Eocene age. At this locality no extensive mud flows of rhyolitic character appear to have reached the valley, although they are abundantly present in the longitudinal basin which begins at North Columbia, Nevada County, 15 miles east. At the mouth of the Tertiary Calaveras River, on the other hand, shore gravels or delta gravels spread out up to a present level of 500 feet, and these gravels rest on the gently eroded surface of the Ione formation.

These interrhyolitic gravels were again subjected to some erosion; immediately after this followed the prolonged epoch of andesitic flows. The tuffs which were spread over a large part of the Sierra Nevada were worked over by the rivers and spread as thick masses of volcanic gravels and sands over the eroded surface of the Ione formation and the interrhyolitic gravels.

The "gravels of interrhyolitic age" resting upon "the eroded surface of Ione", described by Lindgren are in reality of *andesitic* or

interandesitic age. In the locality figured in Pl. 11 B, p. 72, of his "Tertiary Gravels of the Sierra Nevada," the gravels contain abundant boulders of andesite as well as rhyolitic fragments. Turner⁵⁹ describes this locality as follows: "This conglomerate consists of a variety of pebbles—quartzite, mica schist, quartz-porphyrity, granitoid rocks, *andesite*, and rhyolite being represented."

From Lindgren's excellent statement and the conditions described above at Oroville Table Mountain it is evident that a correlation between the Tertiary gravels and the Ione is made possible. Lindgren recognizes the following divisions in the Tertiary gravels and the volcanic formations associated with them: *a*, Deep gravels of Eocene age; *b*, bench gravels; *c*, rhyolitic tuffs and interrhyolitic channel; andesitic tuffs and intervolcanic channel. The accompanying figure copied from Lindgren's paper shows the relations of these deposits graphically (see figure 7). A fourfold division of the

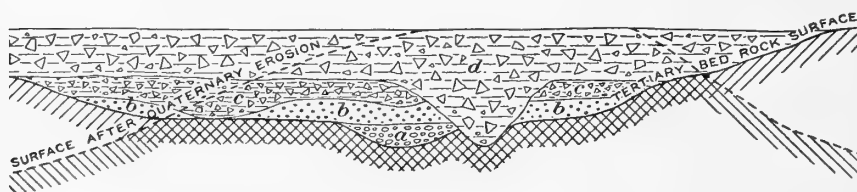


Fig. 7. Schematic representation of the four principal epochs of Tertiary gravels in the Sierra Nevada. *a*, Deep gravels (Eocene); *b*, bench gravels (Eocene); *c*, rhyolitic tuffs and interrhyolitic channel; *d*, andesitic tuffs and intervolcanic channel. (Adapted from Lindgren.)

Ione is better for the purpose of correlation than Turner's threefold division. The lowermost division in the type locality of the Ione is (1) the sand and gravel member in the bottom of the deep basin near Ione, 500 to 600 feet; (2) clays derived from rhyolite with interbedded lignite, 100 to 200 feet; (3) white and red coarse-grained sandstone with scales of alunite, 25 to 75 feet; (4) rhyolite and its clay derivatives ("clay rock" of Turner), 0 to 50 feet. Andesitic tuffs or their equivalents, the Neocene shore gravels, are sometimes found resting upon the third or the fourth member of the Ione. The probable relationship between the lowermost member of this sequence and the deep gravels was indicated by Lindgren: "Near Valley Springs the Ione attains elevations of 1000 feet, and its highest members are probably several hundred feet above the deepest gravels of

⁵⁹ Turner, H. W., Rocks of the Sierra Nevada, Fourteenth Annual Report, U. S. Geological Survey, p. 468, 1894.

the Tertiary Calaveras River, which here debouches into the plains but which is not visible in this vicinity". Evidently the deep gravels should be correlated with the basal sands and gravels of the Ione; the rhyolite and inter-rhyolitic channel has an equivalent in the last three members of the Ione; the andesite of the Sierras is coextensive with the andesitic tuffs and Neocene shore gravels of the valley border.

The third member of the Ione, the red sandstone, contains casts of *Venericardia planicosta merriami* and other Eocene shells which are characteristic of the *Siphonalia sutterensis* zone of the Tejon group; hence the lower portion of the rhyolitic beds and the inter-rhyolitic channel, the correlatives of second and third members of the Ione formation, are Eocene in age. No fossils have yet been found in the fourth member of the Ione, the "clay rock" of Turner. This correlative of the uppermost portion of the rhyolite of the Sierra Nevada is apparently conformable with the third, the red sandstone member. On the basis of stratigraphy, the fourth member is probably Eocene in age, in part at least. If there is any genetic connection between the white shale of the Coalinga District and the rhyolite of the Sierra Nevada, then an Oligocene age is suggested for the uppermost part and Eocene age for the lower portion. However, as interesting as this possibility may be, it is a difficult one to verify and its consideration is merely a suggestion for future investigation.

Wide-spread unconformity between the andesite and the rhyolite is shown in many places in the Sierra Nevada, and the same relations exist between their correlatives of the valley border, the Neocene shore gravels and the uppermost rhyolitic member of the Ione. In places the andesite is coextensive with the andesitic tuffs which overlie the rhyolite of the uppermost Ione; hence the stratigraphic relations between the andesite of the mountains and the andesitic tuffs of the valley border are entirely clear. The andesitic tuffs have yielded several floras, but no fauna which is properly authenticated has been reported from them.

The floras listed by Knowlton⁶⁰ from Corral Hollow and south of Mount Diablo are both from the San Pablo, an upper Miocene formation as determined by Clark.⁶¹ The age determination of the andesitic tuffs will probably be made when larger floras from the

⁶⁰ Knowlton, F. H., Flora of the Auriferous Gravels of California in Tertiary Gravels of the Sierra Nevada of California, Professional Paper No. 73, U. S. Geological Survey, pp. 57 to 64, 1911.

⁶¹ Clark, Bruce L., The Fauna of the San Pablo Group, Univ. Calif. Publ. Bull. Dept. Geol., vol. 8, pp. 442-443, 1915.

marine Miocene formations of the Coast Ranges are carefully compared with those of the Sierran andesitic tuffs.

The determination of the age of the rhyolitic and inter-rhyolitic channels as Eocene differs from previous age determinations. The previous evidences of age were vertebrate remains and floras from the bench gravels and rhyolitic tuffs. Unfortunately the vertebrate localities are uncertain. Lindgren says:

The number of species of clearly pre-volcanic occurrence is not large. The most important localities are Douglas Flat and Chili Gulch, in Calaveras County, and the Tuolumne Table Mountain not far to the south, in Tuolumne County. In the Calaveras County localities bones and teeth of a species of rhinoceros, described by Leidy under the name of *R. hesperius*, have been discovered. At Douglas Flat was also found a tooth of the pachyderm *Elotherium*, which belongs to the Eocene or Oligocene (White River Group of the Rocky Mountain region) . . . These few occurrences complete the list of fossils which Whitney considered authentic and beyond doubt derived from the Tertiary gravels.

The forms might represent either Oligocene or Eocene species.

Knowlton⁶² who has studied all of the floras of the West Coast described the life conditions of the flora of the auriferous gravels in a note to Diller as follows:

Lesquereux, as you have already stated, argued that the presence of a large number of lauraceous plants indicated a region analogous in atmospheric conditions to Florida. From my own studies which embrace a much larger amount of material than Lesquereux had, I am not only prepared to accept this statement, but to show that it now has stronger support than he could have given it. Lesquereux knew only about 50 species of plants in the auriferous gravels, whereas the present known flora embraces nearer twice that number. Of this number the following genera are distinctly tropical or subtropical in their distribution: *Laurus* (4 species), *Persea* (3 species), *Cinnamomum* (2 species), and *Oreodaphne* (2 species), all belonging to the Lauraceae. In addition to these there is *Artocarpus* and *Zizyphus*, each with 2 species, *Ficus* with 6 species, and *Sabalites* with 1 species, or 22 species in all, representing at least 20 of the entire present flora. The present flora of Florida has only 5 genera and 8 species belonging to the Lauraceae, which represent less than one per cent of the whole flora, while, as stated above, there are 4 genera and 10 species in the auriferous gravels, representing fully ten per cent of that flora.

Following is a list of genera, with the number of species in each having living representatives confined in the main to temperate regions, some of them growing at elevations at or but little above sea level: *Aralia* (4), *Platanus* (2), *Cornus* (4), *Juglans* (5), *Liquidambar* (1), *Magnolia* (4), *Quercus* (15), *Viburnum* (3), *Rhus* (6), *Alnus* (3). Of course it is quite impossible to say that these species actually grew at the above alti-

⁶² Knowlton, F. H., in *Topographic Revolution on the Pacific Coast*, Fourteenth Annual Report, U. S. Geological Survey, Part II, p. 421, 1894.

tude, but simply that from what we know of the living species, some or perhaps all of them may have done so. That is, there are none of these genera confined to high elevations. On the other hand there are a number of genera as *Alnus*, *Betula*, *Populus*, *Salix*, etc., that we would hardly expect to find in great abundance at a very low altitude, but like the last mentioned genera, they are not exclusively confined to high altitudes. They might well have grown on land in close proximity to a body of water connected with the sea, such as the area under discussion appears to have been during their deposition. There are also several genera of conifers, as *Pinus*, *Araucarioxylon*, *Cupressinoxylon*, *Pityoxylon*, which alone would appear to argue a greater elevation than appears to have prevailed. If these genera were in great abundance, it would still further strengthen that view, but on the contrary they are very rare, the genus *Pinus* being represented by a single somewhat doubtful example. From their lightness and well-known power of long resisting the processes of decay, they might well have been transported from long distances, for with the exception of the pine-needles there is no evidence to show that any of them grew where they were fossilized.

From these facts Diller⁶³ concluded "that during the Miocene the country was a series of plains and peneplains with low mountain ranges; or in other words, the country was but little above its base level of erosion".

Lindgren's⁶⁴ very careful work on the Tertiary topography of the Sierra Nevada alters this conception considerably and places before us an indisputable body of facts.

The evidence available shows conclusively that at the time when the oldest gravels, probably of Eocene age, began to accumulate the Sierra Nevada was a mountain range as distinct if not as high, as at present. The rivers headed near the points where the corresponding modern rivers begin now, in a region of lofty peaks and ridges. In geologic literature it has been repeatedly stated that the Tertiary surface of the Sierra Nevada is that of a peneplain, a conclusion absolutely at variance with the opinions of those who have actively studied the range. . . .

The Tertiary topography of the western slope consisted of four units. Along the valley line extended a number of greenstone ridges attaining elevations of 1,500 to 4,000 feet. They are shown perfectly plainly in Yuba and Butte counties, for instance, by Brown's Valley Ridge and the Oregon Hills, through which the Yuba river of Tertiary time broke through in a deep canyon. In Placer County an area of softer granodiorite reached the valley and in this vicinity—for instance, near Rocklin—the idea of a peneplain is more nearly realized than elsewhere. In Calaveras County, the Tertiary Calaveras River broke through this barrier in a deep valley similar to that of the lower Yuba but much more abrupt; near San Andreas, for instance, these greenstone ridges rose 2,000 feet above the river in a deep canyon. In Placer County an area of softer granodiorite reached prominently emphasized in the Peñon Blanco Ridge and Bullion Mountains.

⁶³ *Idem*, p. 422.

⁶⁴ Lindgren, Waldemar, The Tertiary Gravels of the Sierra Nevada of California, Professional Paper 73, U. S. Geol. Surv., p. 37.

A study of Knowlton's list as given in Lindgren's "Tertiary Gravels of the Sierra Nevada" shows that most of the forms mentioned by him above as showing a subtropical climate were found in the bench gravels or the rhyolitic tuffs.

The mixture of plants of the lowlands and plants of the highlands to which Knowlton refers is explained in part by the facts that his fauna is a mixture of forms obtained from the andesites and from the bench gravels and rhyolite, and in part by Lindgren's clear picture of a mountainous region of fairly great relief bordering a coastline. The fact that many of the species are subtropical is not contrary to the conclusions concerning Eocene climate which the writer derived from the study of the marine invertebrates of the Tejon Eocene. In fact a subtropical climate is inferred from both studies and hence there is nothing in the floras which would reject an Eocene age determination for the bench gravels and the rhyolite.

In addition to this, some direct evidence concerning Eocene floras was obtained by Diller. Several of the species listed by Knowlton⁶⁵ have also been reported from a known Tejon locality in Oregon. Among these were *Magnolia lanceolata* and *Aralia whitneyi*. Concerning this flora Knowlton remarks that "they have both been reported from the Fort Union formation as well as from the Ione formation of Shasta County, California, and other localities . . . a fact which undoubtedly robs them of the significance they might otherwise have as tending to prove the Eocene age of all the auriferous gravels". Knowlton assumed a proven Miocene age for the Ione. This assumption may be due to the determination of some poorly preserved marine fossils from the supposed Ione of the Marysville Buttes as Miocene. Better material obtained from this locality demonstrates the Eocene age of these beds. It has been shown above that the age of the Ione is Eocene and hence this evidence supports an Eocene age for the auriferous gravels most decidedly. Thus far there is no evidence which can not be legitimately interpreted as indicating an Eocene age for the deep gravels and most of the rhyolite of the superjacent series of the Sierra Nevada.

SUMMARY OF GEOLOGICAL EVENTS ALONG THE WESTERN FOOTHILLS OF THE SIERRA NEVADA

The historical geology of the east side of the Great Valley border from Chico time to the Recent is in summary:

⁶⁵ Knowlton, F. H., in Professional Paper No. 73, p. 64, 1911.

- (1) Pre-Chico erosion.
- (2) Chico transgression. Shore line moves eastward to present elevations of 300 feet.
- (3) Post-Chico erosion. Shore line moves west of the eastern valley border.
- (4) Ione (Eocene) transgression. Shore line moves eastward at least to present elevations of 1000 to 1200 feet.
- (5) Post-Ione erosion. Shore line moves permanently west of valley border.
- (6) Deposition of interandesitic shore gravels.
- (7) Pliocene and Pleistocene erosion—Sierran period.
 - (a) Deposition of "Pleistocene shore gravels" up to elevation of 450 feet.
 - (b) Deepening of stream beds along valley border by 100 to 300 feet.
 - (c) Deposition of lower bench gravels.
 - (d) Deposition of present alluvium.

Such in brief outline is the series of events as interpreted in accordance with the results given above. This sequence does not apply to the southern end of the valley border, as a different series of events seems to have taken place in that region.

SUMMARY

(1) The sedimentary strata beneath the Older Basalt of Oroville Table Mountain and Oroville South Table Mountain represents the uppermost Tejon of California, the *Siphonalia sutterensis* zone.

(2) The beds beneath the Older Basalt are strand-line deposits.

(3) The auriferous gravels as represented by the channels exposed at the Cherokee Mine and in Morris Ravine are stream-laid deposits, the correlatives of the marine sediments exposed at Oroville South Table Mountain and hence their age is Tejon Eocene.

(4) The correlative of the so-called Ione formation is represented in the Marysville Buttes region by deep-water sediments of Tejon age. These strata have yielded an abundant fauna which has a close relationship to the littoral fauna of Oroville and other Ione localities.

(5) The Ione formation is of Eocene age and is merely a facies of the Tejon group. If the name is retained, it should be interpreted as the uppermost or *Siphonalia sutterensis* zone of the Tejon group.

(6) The Ione has been repeatedly correlated with the auriferous

gravels of the Sierras and the upper portion with the rhyolitic tuffs. It can no longer be doubted that the Ione is of the same age as the rhyolitic tuff and the bench and deep gravels, and since the Ione is clearly Tejon-Eocene, the correlatives must be upper Eocene, at least in part, and the land equivalent of the marine Tejon.

TEJON GROUP IN THE VICINITY OF FORT TEJON

STRATIGRAPHY

The Tejon group at the type locality is a portion of an east-west strip which extends from Tunis Creek on the north flanks of the Tehachapi Mountains to a point about three miles southeast of Pattiway where it is cut off by the San Andreas Fault. The map (see figure 8) which is adapted from the "Preliminary Report on the Geology and Possible Oil Resources of the South End of the San Joaquin Valley, Cal.," by Robert Anderson shows the general distribution of the Tejon very satisfactorily.

The Tejon strata in the vicinity of Grapevine Creek rest upon a Basement Complex consisting of granite rocks and associated schists. The beds in general have a steep north dip of 75° to 85° but are disturbed in places so that the dip is reversed. The basal member about 250 to 300 feet in thickness consists of a very coarse conglomerate derived from the granitic rocks of the Basement Complex. This member is overlain by about 1000 to 1200 feet of thin-bedded brown sandstone with subordinate strata of dark gray, clay shale containing limestone nodules. The sandstone is, in places, conglomeritic and in one locality the dark gray pebbles of shale yielded a small pecten. The occurrence of this pecten suggests the deposition of Cretaceous deposits which were completely removed during upper Eocene time. The uppermost strata, about 1200 feet in thickness, consist chiefly of light tan sandstone with subordinate strata of shale and brown sandstone. The total thickness of the Tejon group along Grapevine Creek (Cañada de las Uvas) is about 2500 feet. The Tejon is overlain by volcanic ash of Oligocene or Miocene age on the west side of Grapevine Creek. Martin states that the uppermost Tejon beds in Live Oak Creek are covered by a lava flow.

FAUNA

The middle portion of the Tejon group in the vicinity of Grapevine Creek is particularly rich in upper Eocene species. The basal beds yielded but a small fauna (Cal. Acad. Sci. locality 246) which

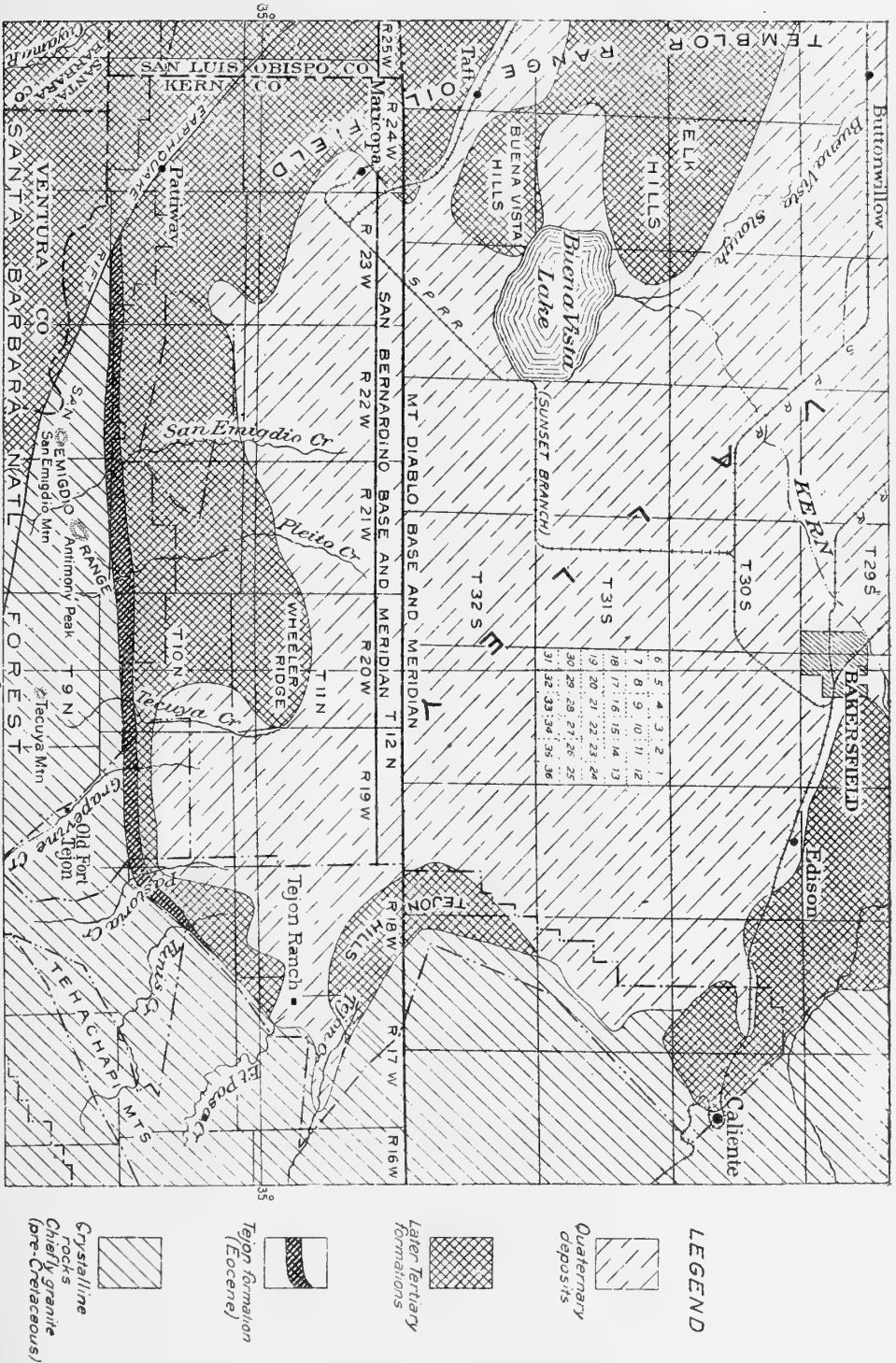


Fig. 8. Map showing type locality of Tejon group. (After R. Anderson.) Scale 1:500,000.

consists of *Spondylus carlosensis*, *Barbatia*, sp., *Meretrix*, sp. and *Ostrea*, sp.

Beds about 300 feet above the base (Univ. of Cal. locality 458) yielded an excellent fauna. This fauna, however, does not differ essentially from that of the beds higher in the section. The faunas from several other localities which are listed below do not differ materially from one another but all appear to represent one phase. This faunal unity is in consonance with the sedimentary record as Anderson⁶⁶ described it: "The beds throughout possess a marked similarity and give every appearance of representing a period of continuous deposition in one basin. They are therefore to be regarded as making up a formation, and not a larger division of the geologic column." The writer is in complete agreement with Anderson's views as expressed here in relation to the type Tejon. However, beds both higher and lower than the Eocene of Cañada de las Uvas occur in other parts of the state, notably in the vicinity of Mount Diablo, along Cantua Creek, Coalinga Quadrangle and at the Marysville Buttes. Owing to these facts the expression "Tejon group" is fully warranted upon both stratigraphic and faunal grounds.

The fauna of the type Tejon corresponds to the Rimella simplex zone of the Mount Diablo region.

LIST OF SPECIES FROM TYPE LOCALITY OF TEJON

<i>Turbinolia</i> , sp.	<i>Dosinia elevata</i> Gabb
<i>Dendrophyllia tejonensis</i>	<i>Glycimeris sagittatus</i> (Gabb)
Nomland	<i>Glycimeris fresnoensis</i> , n. sp.
<i>Schizaster lecontei</i> Merriam	<i>Glycimeris eocenicus</i> (Weaver)
<i>Acila gabbiana</i> , n. sp.	<i>Glycimeris ruckmani</i> , n. sp.
<i>Arca hornii</i> Gabb	<i>Leda gabbi</i> Conrad
<i>Avicula pellucida</i> Gabb	<i>Leda uvasana</i> Dickerson
<i>Barbatia morsei</i> Gabb	<i>Lucina cumulata</i> Gabb
<i>Crassatellites uvasana</i> Gabb	<i>Lucina</i> , cf. <i>cretacea</i>
<i>Crassatellites grandis</i> Gabb	<i>Lucina</i> (<i>Myrtaea</i>) <i>taffana</i> , n. sp.
<i>Crassatellites mathewsonii</i>	<i>Lucina gyrata</i> (Gabb)
(Gabb)	<i>Lucina nasuta</i> Gabb
<i>Cardium brewerii</i> Gabb	<i>Macrocallista andersoni</i> Dickerson
<i>Cardium cooperii</i> Gabb	<i>Macrocallista conradiana</i> (Gabb)
<i>Cardium</i> , cf. <i>olequahensis</i> Weaver	<i>Marcia quadrata</i> (Gabb)
<i>Corbula hornii</i> Gabb	<i>Meretrix hornii</i> Gabb
<i>Corbula parilis</i> Gabb	<i>Meretrix ovalis</i> Gabb
<i>Corbula harrisi</i> , n. sp.	<i>Meretrix tejonensis</i> Dickerson
<i>Corbula uvasana</i> , n. sp.	<i>Meretrix uvasana</i> Conrad

⁶⁶ Anderson, Robert. Preliminary Report on the Geology and Possible Oil Resources of the South End of the San Joaquin Valley, Cal., Bull. 471, U. S. Geol. Surv., p. 118, 1912.

LIST OF SPECIES FROM TYPE LOCALITY OF TEJON—(Continued)	
Meretrix, cf. olequahensis	Fusinus tumidus Gabb
Weaver	Galeodea tuberculata (Gabb)
Modiolus ornatus (Gabb)	Hemifusus lewisiana Weaver
Macoma, sp.	Lunatia hornii Gabb
Nucula cooperi Dickerson	Lunatia nuciformis Gabb
Ostrea, sp.	Murex sopenahensis Weaver
Psammobia hornii (Gabb)	Mitra simplicissima Cooper
Psammobia, sp.	Mitra uvasana Dickerson
Pinna barrowsi Dickerson	Naticina obliqua Gabb
Spisula merriami Packard	Natica uvasana Gabb
Solen parallelus Gabb	Natica hannibali Dickerson
Septifer dichotomus Gabb	Neverita secta Gabb
Spondylus carlosensis Anderson	Nyctilochus kewi Dickerson
Tellina remondii Gabb	Nyctilochus, sp. a.
Tellina howardi Dickerson	Nyctilochus hornii (Gabb)
Tellina californica Gabb	Nyctilochus washingtoniana (Weaver)
Tellina joaquinensis Arnold	Nyctilochus sopenahensis (Weaver)
Teredo, sp.	Nyctilochus cowlitzensis (Weaver)
Venericardia planicosta hornii (Gabb)	Nyctilochus fusiformis (Gabb)
	Nyctilochus californicus (Gabb)
Cadulus pusillus Gabb	Olivella mathewsonii Gabb
Dentalium stramineum Gabb	Odostomia, sp. a.
Actaeon moodyi, n. sp.	Odostomia packi Dickerson
Amauropsis alveata (Conrad)	Perissolax blakei (Conrad)
Amauropsis andersoni Dickerson	Potamides, sp.
Architectonica hornii Gabb	Pseudoliva tejonensis Dickerson
Architectonica cognata Gabb	Pseudoliva volutaeformis Gabb
Ancillaria elongata Gabb	Rimella simplex Gabb
Bullaria hornii (Gabb)	Surcula io (Gabb)
Cancellaria stantoni Dickerson	Surcula (Surculites) sinuata Gabb
Calyptraea excentrica (Gabb)	Surcula cowlitzensis Weaver
Conus remondii Gabb	Surcula washingtoniana (Weaver)
Conus weaveri, n. sp.	Siphonalia bicarinata Dickerson
Conus cowlitzensis Weaver	Spiroglyphus(?) tejonensis Arnold
Conus hornii Gabb	Terebra californica Gabb
Conus californiana (Conrad)	Turritella uvasana Conrad
Crepidula pileum Gabb	Turritella uvasana bicarinata Dickerson
Cylichna costata Gabb	
Cypraea mathewsonii Gabb	Turritella uvasana tricarinata Dickerson
Cypraea bayerquei Gabb	
Cerithiopsis alternata Gabb	Turritella buwaldana Dickerson
Chrysodomus ruckmani, n. sp.	Turritella kewi Dickerson
Drillia raricostata Gabb	Turris uvasana, n. sp.
Drillia ullreyana Cooper	Turris monolifera Cooper
Exilia harrisi Dickerson	Turris stocki, n. sp.
Exilia dickersoni (Weaver)	Turris, sp.
Epitonium tejonensis, n. sp.	Voluta martini Dickerson
Fasciolaria sinuata Gabb	Voluta slevini Dickerson
Ficopsis remondii Gabb	Voluta, sp.
Ficopsis hornii Gabb	Whitneya ficus Gabb
Ficopsis cowlitzensis (Weaver)	

TEJON GROUP, CANTUA DISTRICT, COALINGA QUADRANGLE

The great development of Eocene strata in the vicinity of Cantua Creek in the northern portion of the Coalinga Quadrangle and their complicated relationship to the underlying beds have interested several investigators during the last ten years. The age of a portion of these beds has been questioned by some investigators and a portion of these Eocene strata has been assigned to the Martinez group. It is the purpose of this discussion to show that the fauna of the lowermost beds represent a lower zone of the Tejon group and that it is equivalent to the Turbinolia zone of the Tejon group of Mount Diablo. A great difficulty in the investigation of the Tejon group is found in the incomplete description of its fauna. It has been the writer's experience in collecting in the Tejon group that new forms will be found at practically all places where the preservation is slightly better than usual.

HISTORICAL

F. M. Anderson⁶⁷ was the first writer to describe the beds in the vicinity of Cantua Creek. He says:

The preceding list of fossils contains representative Eocene species such as indicate that the beds are to be correlated rather with the Tejon than with the Martinez division of the Eocene, and this accords with the fact that the latter horizon has been considered local in its occurrence, or extending only northward from the latitude of Mount Diablo, and also with the fact that the Tejon Beds are found at New Idria and other points only a few miles north of the limits of our own observations.

In a later paper⁶⁸ he suggested a Martinez age for the lowermost beds.

This area is also referred to by Arnold and Anderson.⁶⁹

J. A. Taff⁷⁰ described the stratigraphy of this region and suggested that the lowermost Eocene beds might be of Martinez age. He described an unconformity between these beds and the Domengine sands.

Professor E. T. Dumble⁷¹ gave further notes upon the strati-

⁶⁷ Anderson, F. M., A Stratigraphic Study in the Mount Diablo Range of California, Proc. Cal. Acad. Sci. Third Series, vol. 2, pp. 162-168.

⁶⁸ A Further Stratigraphic Study in the Mount Diablo Range of California, Proc. Cal. Acad. Sci. Fourth Series, vol. 3, pp. 13-14, 1908.

⁶⁹ Arnold, Ralph and Anderson, Robert, Geology and Oil Resources of the Coalinga District, California, Bull. 398, U. S. Geol. Surv., pp. 62-71, 1910.

⁷⁰ Taff, J. A., Proc. Palaeontological Society, 1912.

⁷¹ Dumble, E. T., Notes on Tertiary Deposits near Coalinga Oil Field and their Stratigraphic Relations with the Upper Cretaceous, Jour. Geol., vol. 20, pp. 28-37, 1912.

graphy and referred a portion of the Eocene strata to the Martinez. His description of the stratigraphic sequence is as follows:

To Messrs. Stanton, Merriam, Weaver and Dickerson is due the credit of demonstrating in the Mount Diablo region the existence below the Tejon of a series of beds of Eocene age, which is clearly distinguishable from that terrane by its characteristic fauna and unconformable relationship. This has been named the Martinez, but only meager accounts of its stratigraphy are available and its existence was recognized at only a few localities.

Our work now proves that this lower member of the Eocene is of very considerable extent southward on the west side of San Joaquin Valley; that it consists of three or more clearly defined members, and that, in addition to the unconformity already described between it and the Cretaceous, there also exists a decided unconformity between it and the overlying Tejon.

The Martinez is well developed in Townships 17 and 18 South, Ranges 13 and 14 East, in the Salt Creek-Cantua region, and comprises a basal bed of chocolate sands with glauconitic sands overlain by yellow sands and conglomerates and these overlain in turn by other chocolate shales. The generalized section of the Martinez in this particular area may be stated as follows:

3. Upper chocolate shales comprising bluish shales at top, grading down into chocolate or brown shales which weather to clays.
These rest upon other chocolate shales which become sandier toward bottom. These shales vary in thickness. 600-900 ft.
 2. Yellow sand and conglomerate.
Bluish sandy shales and thin sandstone, variable in thickness. 200 ft.
Massive yellow sandstone with large dark brown segregations and concretions and some layers of bluish sandy shale.
Fine sand with local beds of conglomerate interbedded with blue and brown shales; a considerable amount of glauconitic material at base. 300 ft.
 1. Lower chocolate shales.
Beds of chocolate and brown shale with small ferruginous and limy concretions and layers of glauconitic sands. 1000 ft.
-
- 2,700 ft.

Dumble lists species collected "from the top of the lower chocolate shales at a locality on Salt Creek in the SW $\frac{1}{4}$ of NW $\frac{1}{4}$, Section 25, Twp. 18 S, R. 14 E."

The greatest surface exposure of these beds in this area is found in Twp. 17 S., R. 13 E., where except for a band of Cretaceous along the south line they form the surface rocks for the entire southern half of the township. The exposure of the lower shale is only a half to three-quarters of a mile in width and the upper shale occupies a similar belt, but the yellow sandstone member has an average breadth of exposure of nearly two miles. On the eastern line of this township this is narrowed

to half a mile and the three members cross the north line of Twp. 18 S., R. 14 E., with a total width of less than two miles. This is again narrowed toward the southeast until in Sec. 23 of this township the upper brown shale and the greater part of the yellow sand has been removed by pre-Tejon erosion, and, south of that point, so far as it occurs, the Martinez is represented beneath the Tejon only by the basal shale with a thin band of yellow sand overlying it through a part of the area.

Tejon Formation

The series of sediments here assigned to the Tejon admit of separation into two distinct members; the lower of white sand and conglomerate carrying a fauna in all respects identical with that of the original Tejon locality, and an upper member of white shale which is not so fossiliferous and which, as has been suggested by different investigators in this area, may in part or as a whole represent the Oligocene.

The general section of the Salt Creek-Cantua region is as follows:

5. White shale.	Feet.
White fissile organic shales, containing fish scales, teeth, foraminifera, etc.....	500
Lenses of fine brown sand.	
White shale with local thin sandy strata.....	1000
Local friable sand.....	0-30
Pink to white shale.....	200
Bluish sandy shales grading up into pink shales.....	40
	<hr/>
	1,770
4. White sandstone and conglomerate.	
Yellowish to white, usually fine sand.....	100-160
White massive sandstone and conglomerate with whitish shale inclusions at the base.....	20-40
	<hr/>
	200

In this portion of the field the base of the Tejon is a fossiliferous conglomerate and sandstone which shows distinct unconformity with the underlying Martinez. Thus, on the east line of Section 17, Twp. 19 S., R. 15 E., the base of the conglomerate is upon an oxidized zone and the massive sandy shale immediately below the conglomerate is cut by numerous burrows that appear to have been made by crustaceans, in some cases extending down to a depth of three feet. These burrow holes have been filled with ferruginous sand and gravel conglomerates that are connected directly with the overlying conglomerate. To the northeast, in Twp. 17 S, R. 13 E, where the conglomerate rests upon the upper shale of the Martinez, it contains shale inclusions at the base.

STRATIGRAPHY

The stratigraphy in the vicinity of Cantua and Salt Creek is in a broad way simple; but in detail it is highly complicated (see figure 9). Beds ranging in age from Jurassic-Franciscan to the Pleistocene form a great eastward dipping monocline. The Shasta-

Chico series are overlain by Tejon Eocene which in turn is overlain by white shales of probably Oligocene age. Middle Miocene strata, the Temblor of Anderson, the Santa Margarita, the Etchegoin formation, and the Tulare occur in succession, as one travels toward the San Joaquin Valley. The "lower chocolate shales" of Dumble are divisible into two portions, the lower portion of which is characterized by the abundance of nodules of barite, while the upper portion, which yielded an Eocene fauna, is characterized by a sandy clay shale slightly different in color and texture from the underlying chocolate shale of probably Cretaceous age. This upper shale is decidedly glauconitic and a two-foot bed of glauconitic sandstone charged with *Turritella andersoni*, n. sp., and many other Eocene fossils is another minor but characteristic stratum. The unconformity described by Dumble is at the base of Anderson's Domengine sands, the beds beneath the white shale. The evaluation of this unconformity will be discussed after the faunas from the Domengine sands, and the underlying shales are presented.

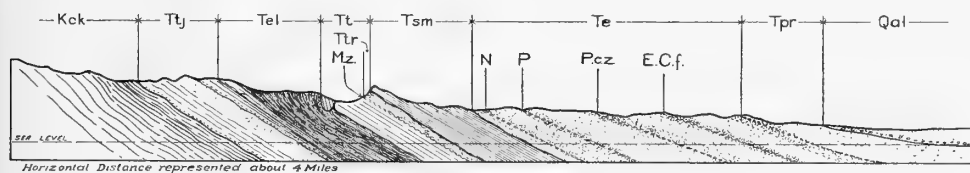


Fig. 9. Section showing Tejon group and associated strata in the vicinity of Domengine Ranch, Coalinga Quadrangle. (After Ruckman.)

FAUNA FROM LOWERMOST BEDS

Turritella andersoni, n. sp. is found in great abundance in the fauna from the glauconitic sandstone stratum mentioned above. This new species gives a peculiar cast to this Eocene fauna and, taken together with several new species in it made at first a very perplexing problem. Large collections from Cañada de las Uvas, the type locality of the Tejon group, vicinity of Mount Diablo, San Diego, and State of Washington have furnished such excellent comparative material that the solution has been greatly simplified.

The species obtained from the lowermost horizon are as follows:

LIST OF SPECIES FROM UNIVERSITY OF CALIFORNIA LOCALITY 1817

	Type Tejon	Turbinolia Zone
Nummuloid, sp. indet.	X
Trochocyathus imperialis Nomland
Flabellum (?) merriami Nomland.....

LIST OF SPECIES FROM UNIVERSITY OF CALIFORNIA LOCALITY 1817—(Continued)

	Type Tejon	Turbinolia Zone
<i>Turbinolia dickersoni</i> Nomland	×
<i>Turbinolia pusillanima</i> Nomland	×
<i>Coral</i> , sp. indet.
<i>Cidarid</i> (?) spine.
<i>Acila gabbiana</i> , n. sp.	×	×
<i>Arca hornii</i> Gabb	×	×
<i>Cardium brewerii</i> Gabb	×	×
<i>Cardium cooperii</i> Gabb	×	×
<i>Crassatellites lillisi</i> , n. sp.
<i>Corbula parilis</i> Gabb	×	×
<i>Dosinia</i> , sp.(?)
<i>Glycimeris cor</i> (Gabb)	×	×
<i>Glycimeris fresnoensis</i> , n. sp.	×
<i>Glycimeris sagittatus</i> (?) (Gabb)	×	×
<i>Isocardium tejonensis</i> Warin
<i>Lucina</i> (?), sp.
<i>Leda fresnoensis</i> , n. sp.
<i>Leda gabbii</i> Conrad	×	×
<i>Meretrix ovalis</i> Gabb	×	×
<i>Marcia</i> (?) <i>conradi</i> , n. sp.
<i>Meretrix hornii</i> Gabb	×	×
<i>Modiolus ornatus</i> (Gabb)	×	×
<i>Nucula cooperi</i> Dickerson	×
<i>Ostrea</i> , sp.
<i>Pecten</i> , cf. <i>interradiatus</i> Gabb
<i>Solen</i> , sp.
<i>Spisula</i> (?), sp.
<i>Teredo</i> , sp.
<i>Venericardia planicosta hornii</i> (Gabb).....	×	×
<i>Cadulus pusillus</i> (Gabb)	×	×
<i>Amauropsis</i> , sp.
<i>Architectonica</i> , cf. <i>hornii</i> Gabb	×	×
<i>Ancillaria elongata</i> Gabb	×	×
<i>Bullaria hornii</i> (Gabb)	×
<i>Calyptraea excentrica</i> (Gabb).....	×	×
<i>Cancellaria stantoni</i> Dickerson.....	×	×
<i>Conus hornii</i> Gabb	×
<i>Cylichna costata</i> Gabb	×	×
<i>Chrysodomus supraplicata</i> (Gabb)	×	×
<i>Exilia perkinsiana</i> (Cooper)	×
<i>Ficopsis</i> , cf. <i>hornii</i> Gabb	×
<i>Fusinus</i> (?), sp.
<i>Lunatia nuciformis</i> Gabb	×
<i>Mitra simplicissima</i> Cooper	×
<i>Metula harrisi</i> , n. sp.
<i>Natica, gesteri</i> , n. sp.
<i>Nyctilochus</i> , sp. a.
<i>Nyctilochus</i> , sp. b.
<i>Nyctilochus</i> , cf. <i>californicus</i> (Gabb)	×	×

LIST OF SPECIES FROM UNIVERSITY OF CALIFORNIA LOCALITY 1817—(Continued)

	Type Tejon	Turbinolia Zone
Nyctilochus, cf. whitneyi (Gabb)	×	×
Naticina obliqua Gabb	·	·
Odostomia packi, n. sp.	·	·
Rimella simplex Gabb	·	·
Surcula io Gabb	·	·
Terebra californica Gabb	·	·
Turris guibersoni Arnold	·	·
Turris monolifera (Cooper)	·	·
Turris suturalis (Cooper)	·	·
Turris fresnoensis Arnold	·	·
Turris, sp. a	·	·
Turritella andersoni, n. sp.	·	·
Cancer(?), sp. a	·	·
Cancer(?), sp. b	·	·

Trochocyathus imperialis Nom. occurs at University of California locality 1412 in the middle of the Tejon section south of Diablo. *Turbinolia dickersoni* Nom., *Turbinolia pusillanima* Nom., *Arca hornii*, *Cardium cooperii*, *Cardium breweri*, *Corbula parilis*, *Leda gabbii*, *Meretrix ovalis*, *Meretrix hornii*, *Modiolus ornatus*, *Acila gabbiana*, n. sp., *Venericardia planicosta hornii*, *Ancillaria elongata*, *Cylichna costata*, *Calyptraea excentrica*, are forms which are found in the Turbinolia zone south of Mount Diablo. *Glycimeris cor*, *Glycimeris fresnoensis*, n. sp., *Architectonica hornii*, *Cancellaria stantoni*, *Conus hornii*, *Odostomia packi*, n. sp., *Surcula io*, *Ficopsis hornii*, *Ficopsis remondii*, *Cadulus pusillus*, *Lunatia nuciformis*, *Mitra simplicissima*, *Chrysodomus supraplicata*, *Nyctilochus californicus*, *Nyctilochus whitneyi*, *Naticina obliqua*, *Rimella simplex*, *Terebra californica*, are all characteristic forms at the type locality of the Tejon. *Isocardium tejonensis* Waring, *Nucula cooperi*, *Turris monolifera*, *Turris suturalis*, *Turris perkinsiana*, are all present in the uppermost or Siphonalia suterensis zone, of the Tejon group. *Turritella andersoni*, n. sp., is found in the middle of the Tejon section south of Mount Diablo. *Flabellum merriami*, n. sp., *Crassatellites lillisi*, n. sp., *Marcia (?) conradi*, n. sp., *Leda fresnoensis*, n. sp. *Metula harrisi*, and *Natica*, n. sp., are the only forms which have not been reported from the Tejon at other localities or from the Martinez group. Not a single species which is restricted to the Martinez group occurs in this fauna, and its relationship is undoubtedly close to the fauna of the typical Tejon which is equivalent to the Rimella simplex zone.

Turbinolia pusillanima Nom., *Cancer(?)*, sp. a are characteristic of the Turbinolia zone of the Diablo section (see fig. 1). This

fauna is tentatively placed as the equivalent of this zone. The writer is inclined to regard it as slightly higher than the typical locality of the *Turbinolia* zone owing to the large percentage of species which are present in the type Tejon.

FAUNA OF WHITE SANDSTONE MEMBER

Just below the white shales of Eocene-Oligocene age there is a richly fossiliferous sandstone stratum. This stratum is ordinarily firmly cemented, but at one small cropping, surface waters had in some way removed the cement and left the shells in a perfect state of preservation. Sixty-seven species were obtained from this locality alone. They are listed below under Univ. of Cal. locality 672. This fauna is evidently related to the fauna of the type Tejon, although it contains about fifteen new species. The large number of new species would be very puzzling if it were not for the presence of *Turritella uvasana* and other species typical of the Tejon group. *Turritella uvasana* is a good guide fossil for the middle portion of the Tejon group, but it is not known to occur in the *Siphonalia sutterensis* zone of California, and, if present in the *Turbinolia* zone, is rare.

A faunal list for the vicinity between Cantua and Domengine creeks is given on pages 430-434.

The fauna found at locality 672 when compared with that of the lowermost strata in this region (locality 1817) illustrates the marvelous unity of the entire Tejon fauna. The number of species in common is quite remarkable when one remembers that stratigraphic distance between them is at least 2000 feet. Does this unity mean that only a short geologic time is represented by the intervening strata? The writer does not regard shortness of time as a plausible explanation, but is inclined to believe that uniformity in climatic conditions in upper Eocene time retarded the development of new forms.

Several workers in this field report the existence of a well marked unconformity in the middle of the section. The time represented by this unconformity is difficult to evaluate. The only method at present available is the faunal one, and as has been previously shown the faunas from above and below the unconformity are as a whole quite similar. There is no well marked difference in dip and strike reported along the unconformable contact, but the evidence consists of a sharp change in lithology and the penetration of the underlying strata by crustacean bore-holes which are filled with sand of the overlying

stratum. The unconformity reported is at least not of the same order as the unconformity between the Tejon and Martinez, as the structural and faunal break between these two groups is a great one. A very large number of Martinez species failed to bridge the gap. Such is not the case in the vicinity of Domengine Creek. The writer believes that the time break represented by this unconformity is at most of secondary order, ie., such as might separate two formations within a group.

UNIVERSITY OF CALIFORNIA TEJON LOCALITIES IN COALINGA QUADRANGLE

All the following localities are in the Tejon group, Coalinga Quadrangle, Fresno County, California.

TWP. 18 SOUTH, RANGE 14 EAST, MT. DIABLO BASE LINE AND MERIDIAN.

670. Near W line of Sect. 15, on branch of Salt Creek $\frac{1}{4}$ mile from Salt Creek, in brown clay shale, 10 to 15 feet above the chocolate Chico (?) shale, *Turritella andersoni*, n. sp. horizon. R. E. D. 592. Colls. G. C. Gester and R. E. Dickerson.
671. NW corner, Sect. 24, 100 to 200 feet (stratigraphic) below white shale—white Tejon sandstone contact. R. E. D. 591. Colls. B. Parsons and R. E. Dickerson.
672. SE $\frac{1}{4}$ of NW $\frac{1}{4}$ of Sect. 24, Parson's Peak, in Tejon white sandstone 0-10 feet below white shale. R. E. D. 590. Colls. J. A. Taff, G. C. Gester, B. Parsons and R. E. Dickerson.
1817. SE $\frac{1}{4}$ of NW $\frac{1}{4}$ of Sect. 15, on branch of Salt Creek, near base of Tejon, 75 to 100 feet above the chocolate shale of probable Chico age, in a glauconitic sandstone stratum in clay shale. R. E. D. 586. Colls. Miss Lillis, F. M. Anderson, G. C. Gester and R. E. Dickerson.

TWP. 18 SOUTH, RANGE 15 EAST.

2266. SW $\frac{1}{4}$ of SE $\frac{1}{4}$ of Sect. 29, elevation 1150 feet. Coll. J. Ruckman.

TWP. 19 SOUTH, RANGE 15 EAST.

2286. NE corner of SW $\frac{1}{4}$ of NE $\frac{1}{4}$ of Sect. 9, in last inside-cañon north, elevation 1300 feet. Coll. J. Ruckman.

TWP. 18 SOUTH, RANGE 15 EAST.

2287. SW corner of SW $\frac{1}{4}$ of SE $\frac{1}{4}$ of Sect. 29, in western side of Domengine Cañon. Coll. J. Ruckman.
2290. On crest of ridge overlooking Domengine Creek above apparent unconformity. Coll. J. Ruckman.
2291. NE corner of SE $\frac{1}{4}$ of SW $\frac{1}{4}$ of Sect. 29, elevation 1200 feet. Coll. J. Ruckman.
2292. NW corner of NE $\frac{1}{4}$ of SE $\frac{1}{4}$ of Sect. 32. Coll. J. Ruckman.
2293. Coll. Wm. Forker.
2294. Coll. Wm. Forker.
2295. Coll. Wm. Forker.
2296. Coll. Wm. Forker.
2297. Coll. Wm. Forker.

WHITE SHALES

Mr. John Ruckman studied the white shales overlying the white sandstone member and he found in the shales two faunas, one in their lower portion which is apparently Tejon and another in the uppermost stratum which is apparently Oligocene. The Tejon fauna was a meager one consisting of *Trochocyathus*, cf. *striatus*, *Crassatellites mathewsonii* and some indeterminate forms. A portion of the white shale may represent the *Siphonalia sutterensis* zone in this region. Indirect evidence supports this view. The fauna from locality 672 contains several species which are common in the *Siphonalia sutterensis* zone and their presence suggests that the fauna in the upper portion of the white sandstone member is transitional between that of the *Rimella simplex* zone and the *Siphonalia sutterensis* zone, i. e., it may nearly correspond to the *Balanophyllia* zone of the section south of Mount Diablo. (See figure 10.)

SUMMARY

1 The Eocene strata between Domengine and Cantua creeks, Coalinga Quadrangle, belong to the Tejon group.

2 These strata appear to be equivalent to the Eocene strata in the vicinity of Mount Diablo. They apparently represent a longer portion of Tejon time than the Tejon of the type locality.

3 The fauna of the lowermost beds which is older than the *Rimella simplex* zone, the fauna of the type Tejon, is tentatively correlated as the equivalent of the *Turbinolia* zone of the Mount Diablo region.

4 The fauna of the white sandstone member is as a whole the equivalent of typical Tejon, although the fauna from the uppermost beds may be transitional between the *Rimella simplex* zone and the *Siphonalia sutterensis* zone.

TEJON GROUP IN SAN DIEGO COUNTY

The fauna of the Tejon group of San Diego County is a particularly interesting one, as it occurs in sediments which have undergone but little folding or faulting. Diastrophism was not so marked in southern California in post-Tejon time as in the central and northern parts of the state. On this account, a correlation between the Tejon of San Diego County and the upper Eocene in the

other parts of the state is important. The writer's conclusions from this faunal study are, in brief, that the Tejon of San Diego County is the equivalent of the Tejon of the type locality, the Rimella Simplex zone. (See figure 12.) No other zones of the Tejon group were recognized in this region and no Martinez-Eocene strata were discovered. This study shows that the diastrophic record in Southern California has been quite a different one from that of the southern San Joaquin in the vicinity of Cañada de las Uvas, where Eocene beds have been folded and faulted in an intricate fashion.

The occurrence of the Tejon group near San Diego was recognized early by Gabb⁷² and Cooper.⁷³ Both Gabb and Cooper described several species from the Tejon of Rose Cañon. Fairbanks⁷⁴ reported both Tejon and Chico-Cretaceous from Point Loma, the contact between the two being nearly at sea level. Arnold⁷⁵ reported an angular unconformity between the Tejon group and the Chico near La Jolla:

It is a noteworthy fact that with one exception, wherever the line between the marine Eocene formations (Martinez, Arago, Tejon, etc.) and the Cretaceous beds are either of lower Cretaceous (Knoxville) or middle Cretaceous (Horsetown) age, and that wherever the Eocene rests on the Chico, or upper Cretaceous, excluding the case at San Diego, the unconformity is not angular, and as far as the stratigraphic evidence goes, the two formations represent an apparently uninterrupted period of sedimentation.

The one exception mentioned by Arnold is the Tejon-Chico relation at San Diego. It has been shown elsewhere that angular unconformities occur between the Eocene and Cretaceous in California at several localities. Arnold's discovery of the unconformity at San Diego shows that the same condition prevails here as the writer⁷⁶ has shown to exist in the vicinity of San Francisco Bay.

STRATIGRAPHIC NOTES

The Tejon in the vicinity of San Diego County is associated with underlying Chico-Cretaceous, and with the overlying San Diego Plio-

⁷² Gabb, W. M., *Geol. Surv. Calif. Palaeontology*, vol. I, p. 95, 1864.

⁷³ Cooper, J. G., *Catalogue of California Fossils*, Bull. No. 4, California State Mining Bureau, p. 36, 1894.

⁷⁴ Fairbanks, H. W., *The Geology of San Diego, San Bernardino and Orange counties*, 11th Ann. Report Cal. State Mining Bureau, pp. 76-120, 1894.

⁷⁵ Arnold, Ralph, *Environment of the Tertiary Faunas of the Pacific Coast of the United States*, Jour. Geol., vol. 17, p. 513, 1909.

⁷⁶ Dickerson, R. E., *Fauna of the Martinez Eocene of California*, Univ. Calif. Publ. Bull. Dept. Geol., vol. 8, pp. 61-180, 1914.

cene and Pleistocene terrace deposits. San Diego city is built upon two or three marine terraces and the upper terrace, about 400 feet above the sea, extends northward for many miles. Soledad Mountain, which is five or six miles northwest of San Diego, rises above this terrace, or rather the terrace encircles the mountain. The Tejon is best exposed in the stream cañons east of Soledad Mountain which have trenched the marine terraces. Rose Cañon and Tecolote Creek yield particularly good sections.

The Tejon group in the vicinity of San Diego and La Jolla consists of about 600-700 feet of nearly horizontal strata which underlie most of the "mesa" land around San Diego and La Jolla. These strata consist of beds of clay shale containing nodular limestone and dull red quartzose sandstone typical of the Tejon group throughout the state. One prominent fossiliferous horizon is found about 200 feet above the base. This horizon occurs in Rose Cañon, Tecolote Valley and in other valleys of the vicinity.

FAUNA

The fauna upon which this discussion is based was obtained principally by W. S. W. Kew. The writer spent three or four days in the field with Mr. Kew in the summer of 1913. Chester Stock and Earl L. Packard also contributed to the collections from this vicinity. Most of the specimens were obtained from the fossiliferous horizon which is estimated as 200 feet above the base of the formation. The collection obtained by Mr. Kew from Point Loma, University of California locality 695, was near the base of the Tejon.

LIST OF TEJON FOSSILS FROM LOCALITIES IN AND AROUND SAN DIEGO

	694	695	696	697	2226	Type
						Tejon.
Turbinolia, sp.	×	---	---	---	×	---
Astarte semidentata Cooper	×	---	---	---	×	---
Acila gabbiana, n. sp.	×	---	---	---	×	×
Avicula pellucida Gabb	×	---	---	---	---	×
Barbatia morsei Gabb	---	---	---	×	---	×
Corbula parilis Gabb	×	×	---	---	×	×
Cardium cooperii Gabb	×	---	×	---	×	×
Cardium brewerii Gabb	×	---	×	×	---	×
Crassatellites grandis Gabb	×	---	---	---	---	×
Cardium, sp.	---	---	---	---	×	---
Glycimeris sagittatus Gabb	×	---	---	---	×	×
Isocardium tejonensis Waring	×	---	---	---	---	×
Lucina gyrata (Gabb)	×	---	---	---	×	×
Lucina diegoensis, n. sp.	---	×	---	---	---	---

LIST OF TEJON FOSSILS FROM LOCALITIES IN AND AROUND SAN DIEGO—
(Continued)

	694	695	696	697	2226	Type Tejon.
<i>Leda gabbi</i> Conrad	×	×
<i>Modiolus ornatus</i> (Gabb)	×	×	×	×
<i>Meretrix hornii</i> Gabb	×	×	×	×
<i>Meretrix ovalis</i> Gabb	×	×	×
<i>Meretrix tejonensis</i> Dickerson	×	×	×	×
<i>Ostrea</i> , sp.	×	...	×	×
<i>Placunanomia inornata</i> Gabb	×	×
<i>Paphia</i> , sp.	×	...
<i>Spisula merriami</i> Packard	×	×
<i>Solen</i> , sp.	×
<i>Solen parallelus</i> Gabb	×	×
<i>Macrocallista</i> (Tapes) <i>conradiana</i> (Gabb)	×	×	×
<i>Psammobia hornii</i> (Gabb)	×	×
<i>Tellina remondii</i> Gabb	×	×
<i>Tellina</i> , cf. <i>aequalis</i> Gabb.....	×	×?
<i>Tellina</i> , sp.	×
<i>Tellina jollaensis</i> , n. sp.	×
<i>Venericardia planicosta hornii</i> (Gabb)..	×	×	×	×	×	×
<i>Venus aequilateralis</i> Gabb	×
<i>Dentalium</i> , sp., smooth	×
<i>Dentalium stramineum</i> Gabb	×	×	×
<i>Dentalium cooperii</i> Gabb.....	×	×
<i>Amphissa</i> (?), sp.	×
<i>Architectonica</i> , sp.	×
<i>Amauropsis alveata</i> (Conrad).....	×	×	×
<i>Ancillaria elongata</i> Gabb	×	...	×	...	×	×
<i>Architectonica</i> , sp.	×	...
<i>Cancellaria stantoni</i> Dickerson	×	×
<i>Chrysodomus supraplicata</i> (Gabb)	×	×	×
<i>Cylichna costata</i> Gabb	×	×	×	...	×	×
<i>Conus hornii</i> Gabb	×	×	×
<i>Conus remondii</i> Gabb	×	...	×	×
<i>Crepidula</i> (Spirocrypta) <i>pileum</i> Gabb....	×	×	×
<i>Cerithiopsis alternata</i> Gabb	×	...	×	×
<i>Cypraea mathewsonii</i> Gabb	×	×
<i>Calyptraea excentrica</i> (Gabb)	×	×	×	×
<i>Drillia</i> , sp.	×
<i>Galeodea tuberculata</i> (Gabb)	×	×
<i>Fasciolaria sinuata</i> Gabb.....	×	×	×
<i>Fasciolaria bilineata</i> , n. sp.	×	×	...
<i>Ficopsis</i> , sp.	×
<i>Ficopsis remondii</i> Gabb	×	...	×	...	×	×
<i>Ficopsis cooperii</i> Gabb	×	...	×	...
<i>Fusinus</i> , cf. <i>martinez</i> (Gabb)	×	×
<i>Lunatia</i> , cf. <i>hornii</i> Gabb	×	×	...	×	×	×
<i>Lunatia nuciformis</i> Gabb	×	×

LIST OF TEJON FOSSILS FROM LOCALITIES IN AND AROUND SAN DIEGO—
(Continued)

	694	695	696	697	2226	Type Tejon.
<i>Loxotrema turrita</i> Gabb	---	---	---	×	---	×
<i>Mitra simplicissima</i> Cooper	×	---	---	---	×	×
<i>Mitra uvasana</i> Dickerson	---	---	---	---	×	×
<i>Mitramorpha parsonsi</i> , n. sp.	---	---	---	---	×	---
<i>Megistostoma striata</i> Gabb.....	---	---	---	---	×	---
<i>Metula</i> , cf. <i>harrisi</i> , n. sp.	---	---	---	---	---	---
<i>Naticina obliqua</i> Gabb	×	---	---	---	×	×
<i>Natica uvasana</i> Gabb	×	---	---	---	×	×
<i>Natica hannibali</i> Dickerson	×	---	---	---	×	×
<i>Nyctilochus diegoensis</i> (Gabb)	×	---	---	---	×	---
<i>Nyctilochus pulcher</i> (Weaver)	×	---	---	×	---	---
<i>Nyctilochus hornii</i> (Gabb).....	---	×	×	---	---	×
<i>Nyctilochus</i> , cf. <i>whitneyi</i> (Gabb)	---	×	---	---	×	---
<i>Nyctilochus</i> , sp.	---	---	---	---	×	---
<i>Olivella mathewsonii</i> Gabb	---	---	---	---	×	×
<i>Pseudoliva volutaeformis</i> Gabb	×	---	---	---	---	×
<i>Perissolax blakei</i> (Conrad)	---	---	×	---	×	×
<i>Potamides carbonicola</i> Cooper	---	---	---	×	---	---
<i>Pseudoliva inornata</i> Dickerson	---	---	---	---	×	×
<i>Rimella simplex</i> Gabb	×	---	---	---	×	×
<i>Solariella crenulata</i> (Gabb)	---	---	---	---	×	---
<i>Seraphs erraticus</i> (Cooper).....	×	---	---	---	×	---
<i>Surcula</i> (<i>Surculites</i>) <i>sinuata</i> Gabb	×	---	---	---	---	×
<i>Surcula cowlitzensis</i> Weaver	×	---	---	---	---	×
<i>Surcula supraplanis</i> (Cooper)	---	---	---	---	×	---
<i>Spirogylyphus</i> (?) <i>tejonensis</i> Arnold.....	---	---	---	---	×	×
<i>Turris fresnoensis</i> (Arnold)	×	---	---	---	---	×
<i>Turris</i> , cf. <i>andersoni</i> Dickerson	---	---	---	---	---	---
<i>Tritonium</i> , sp.	---	---	---	---	---	---
<i>Turritella uvasana</i> Conrad	×	×	×	---	×	×
<i>Turritella buwaldana</i> , n. sp.	×	---	---	---	×	×
<i>Xenophora stocki</i> , n. sp.	---	---	---	---	×	---
<i>Aturia</i> , sp.	×	---	---	---	---	---
<i>Nautilus</i> , sp.	---	---	---	---	×	---

The fauna from locality 695 near the base of the Tejon is not particularly different from the faunas at the other localities studied and it is apparent from an examination of the list that but one zone is represented in this vicinity.

COMPARISON OF FAUNA WITH THAT OF THE TYPE TEJON

The species which occur at the type Tejon are indicated in the last column in the list given. Of the 79 forms specifically determined, 62 are reported from the Tejon of Cañada de las Uvas. *Astarte semi-*

dentata Cooper, *Ficopsis cooperii* Gabb, are reported from the upper part of the Umpqua formation in Oregon, *Nyctilochus diegoensis* (Gabb) from the Siphonalia sutterensis zone at Oroville, *Megistostoma striata* Gabb, *Mitramorpha parsonsi* Dickerson, from the top of the white sandstone member of the Tejon north of Coalinga, *Nyctilochus pulcher* (Weaver), from the lowermost green shales of the Tejon in the Pacheco syncline, *Metula harrisi* Dickerson from lower Tejon strata north of Coalinga. *Seraphs erraticus* (Cooper) occurs in the middle section of the Tejon south of Mount Diablo. Of all the forms listed, *Metula harrisi* and *Nyctilochus pulcher* are reported only from the lowermost zone of the Tejon group, the Turbinolia zone. The great number of characteristic species common to the San Diego Eocene and the type Tejon leaves no doubt as to their equivalence, and it is evident that the faunal stage represented at San Diego is that of the Rimella simplex zone. (See figure 12.)

DESCRIPTIONS OF TEJON-EOCENE LOCALITIES IN SAN DIEGO COUNTY

694. La Jolla Quadrangle, San Diego County, California. Tejon group. Lat. $32^{\circ} 47' 30''$; Long. $117^{\circ} 11'$ just east of Morena in Tecolote Cañon. Coll., Wm. Kew and R. E. Dickerson.

695. San Diego Quadrangle, San Diego County, California. Tejon group. Point Loma. Coll., Wm. Kew.

696. La Jolla Quadrangle, San Diego County, California. Tejon group. Lat. $32^{\circ} 48'$; Long. $117^{\circ} 11'$. N. E. of Morena in Tecolote Valley. Coll., Wm. Kew.

697. San Diego Quadrangle, San Diego County, California. Tejon group. San Elijo Valley, McKinnon's Ranch. Coll., Wm. Kew.

2226. La Jolla Quadrangle, San Diego County, California. Tejon group. Lat. $33^{\circ} 50'$; Long. $117^{\circ} 14'$. Rose Cañon, S. E. of Soledad Mountain and N. of Ladrillo Station on Southern Pacific R. R. Colls., Wm. Kew and R. E. Dickerson.

CONCLUSIONS

(1) The Tejon Eocene strata of San Diego County have yielded a fauna of over 90 forms, many of which are common species in the Tejon of Cañada de las Uvas.

(2) The same faunal stage is present in both localities i. e., the Rimella simplex zone.

(3) Orogenic movements in post-Eocene time have been far less vigorous in the vicinity of San Diego than in central California, although equivalent strata occur in both places.

TEJON OF THE SANTA ANA MOUNTAINS

The Tejon of the Santa Ana Mountains is intimately connected with that of San Diego and it represents the Rimella simplex zone. The stratigraphic relations of the Tejon was discussed in a recent paper.⁷⁷ The fauna listed from University of California locality 2243 is as follows:

Cardium, cf. brewerii Gabb	Cerithiopsis, sp.
Solen parallelus Gabb	Cylichna costata Gabb
Tellina, cf. longa Gabb	Ficopsis remondii Gabb
Cadulus pusillus (Gabb)	Natica, sp.
Ancillaria, sp.	Turritella, sp.
Bullaria hornii (Gabb)	Turritella uvasana Conrad

This fauna appears to represent the Rimella simplex zone, as one of its most characteristic species, *Turritella uvasana*, was fairly abundant.

TEJON NEAR LOWER LAKE, LAKE COUNTY, CALIFORNIA

Rocks of Tejon age occupying an elliptical area two and one-half miles long on the eastern portion of the Lower Lake syncline rest upon the Martinez. Coarse gray to white, conglomeritic concretionary sandstone which upon weathering gives rise to bluffs makes up practically its entire thickness, 1100 to 1200 feet. It is lithologically distinct from the uppermost Martinez, which consists of thin-bedded, fine-grained, green-gray sandstone with green shales. No sharp contacts between the Martinez and Tejon were found and hence their relations to one another are not entirely clear. The dips in the Tejon vary from 30° to 35°, while those of the Martinez are, on the whole much higher. This, taken together with a distinct faunal break and abrupt lithological change, leads us to believe that a considerable time-interval elapsed between the deposition of these two groups of the Eocene. Only two fossil localities were found in the Tejon. The fauna found at University of California locality 785, which is about 900 feet above the base of the Tejon group, is as follows:

Crassatellites, cf. uvasana (Gabb)	Meretrix hornii Gabb
Dosinia elevata Gabb	Psammobia hornii (Gabb)
Spisula tejonensis Packard	Solen parallelus Gabb
Meretrix ovalis Gabb	Paphia, cf. cretacea Gabb
Meretrix, sp.	Tellina longa Gabb

⁷⁷ Dickerson, R. E., The Martinez and Tejon Eocene and Associated Formations of the Santa Ana Mountains, Univ. Calif. Publ. Bull. Dept. Geol., vol. 8, pp. 257-274a, 1914.

Bullaria hornii (Gabb)	Naticina obliqua Gabb
Cancellaria marysvillensis	Neverita globosa Gabb
Dickerson	Nyctilochus whitneyi (Gabb)
Drillia cooperi, n. sp.	Surcula (Surculites), cf. sinuata Gabb
Fusinus californicus (Gabb)	Whitneya ficus Gabb
Fusinus, sp.	Serpula, sp.
Lunatia hornii Gabb	Shark(?) tooth

Of the forms listed above, *Dosinia elevata* Gabb, *Meretrix ovalis* Gabb, *Solen parallelus* Gabb, *Tellina longa* Gabb, *Bullaria hornii* Gabb, *Cancellaria marysvillensis* Dickerson, *Fusinus californicus* (Gabb), *Naticina obliqua* Gabb, *Neverita globosa* Gabb, *Nyctilochus whitneyi* (Gabb), and *Whitneya ficus* Gabb are as far as known entirely typical of the Tejon.

This fauna is too meagre for an accurate zonal determination. *Drillia cooperi*, n. sp., is the only form which has not as yet been reported from the type Tejon of Grapevine Creek. This form occurs at University of California Locality 1853 in the Marysville Buttes. Practically all the rest are long-range forms except *Whitneya ficus*, which has not as yet been reported from the Siphonalia sutterensis zone. The fauna does not contain many of the typical species in the Rimella simplex zone, and but one characteristic species of the Siphonalia sutterensis zone. This horizon on this account is tentatively placed in the Balanophyllia variabilis zone.

SUMMARY OF TEJON FAUNA OF CALIFORNIA

The tables given below indicate the occurrence and distribution of the forms which occur in the Tejon group of California. The local occurrence of each species is given in the first major column and the range of the species is indicated in the second. Four faunal zones are recognized in the Tejon, a lowermost, the Turbinolia zone, then the Rimella simplex zone, Balanophyllia variabilis zone and the Siphonalia sutterensis zone, in order. These four zones do not occur in any one locality unless all are represented in the Tejon north of Coalinga, vicinity of Cantua Creek. In this locality the first three appear to be present but the fauna which may represent the fourth is too poor to lead to positive conclusions. The first three zones were originally recognized in the area south of Mount Diablo and the Siphonalia sutterensis zone in the vicinity of the Marysville Buttes and at Oroville. The Rimella simplex zone is, however, more satisfactorily shown at the type locality of the Tejon on Grapevine Creek.

LIST OF TEJON SPECIES REPORTED IN CALIFORNIA

	Mayville Buttes, Oroville, Ione, Merced Falls	Concord Quadrangle North of Mt. Diablo	South of Mt. Diablo	Coalnaga District	Type Tejon	San Diego	Miscellaneous Localities	Martinez Group	Turbidolia Zone	Rimella simplex Zone	Balanophyllia Zone	Siphonalia sutrensis Zone
<i>Cyclammina</i> , sp.....												x
<i>Lagena</i> (?), sp.....												
<i>Nodosaria</i> , sp.....	x			x						x		
<i>Nummulites</i> , sp.....				x								
<i>Orbitoides</i> , sp.....		x		x					x			
<i>Pulvulina</i> , sp.....				x						x		
<i>Polymorphina</i> , sp.....				x								
<i>Sagarina</i> , sp.....				x								
<i>Vaginulina</i> , sp.....				x								
<i>Balanophyllia striata</i> (Gabb).....	x	x			x						x	
<i>Dendrophyllia tejonensis</i> Nomland.....												
<i>Fiabellum</i> (?) merriami Nomland.....												
<i>Fiabellum californicum</i> Vaughan.....	x?	x		x					x			
<i>Stephanophyllia californica</i> Nomland.....	x	x									x	
<i>Trochocyathus</i> (?) perrini Dickerson.....	x											
<i>Trochocyathus stantoni</i> Vaughan.....		x										
<i>Trochocyathus imperialis</i> , Nomland.....		x		x					x			
<i>Turbidolia dickersoni</i> Nomland.....		x		x					x			
<i>Turbidolia pusillanima</i> Nomland.....		x		x					x			
<i>Thamnasteria sinuata</i> Nomland.....		x		x					x			
<i>Cassidulus californicus</i> Anderson.....		x		x					x			
<i>Spatangus</i> (?) pachecoensis Pack.....		x		x								
<i>Schizaster lecontei</i> Merriam.....	x	x			x			x				

LIST OF TEJON SPECIES REPORTED IN CALIFORNIA—(Continued)

	Marysville Buttes Oroville, Ione, Merced Falls	Concord Quadrangle North of Mt. Diablo South of Mt. Diablo	Coalinga District	Type Tejon	San Diego	Miscellaneous Localities	Martinez Group	Turbinolia Zone	Rimella simplex Zone	Balanophyllia Zone	Siphonalia sutlerensis Zone
<i>Scutella</i> , sp.....	×	×	×
<i>Arca clarki</i> , n. sp.....	×	×
<i>Arca hornii</i> Gabb.....	×	×	×	×	×
<i>Acala gabbiana</i> , n. sp.....	×	×	×	×	×	×	×	×	×
<i>Avicula pellucida</i> Gabb.....	×	×	×	×	×	×	×	×
<i>Astarte semidentata</i> Cooper.....	×	×
<i>Barbatia morsei</i> Gabb.....	×	×	×
<i>Barbatia</i> , sp.....	×	×
<i>Cucullaea morani</i> Waring.....	¹.....	.....	.....	.....	.....	×
<i>Crenella concentrica</i> Gabb.....	?
<i>Crassatellites uvasana</i> Gabb.....	×	×	×
<i>Crassatellites grandis</i> Gabb.....	×	×	×	×	×	×	×
<i>Crassatellites fresnoensis</i> Dickerson.....	×
<i>Crassatellites mathewsonii</i> (Gabb).....	×
<i>Cardium linteum</i> Conrad.....	×
<i>Cardium cooperii</i> Gabb.....	×	×	×	×	×	×	×
<i>Cardium brewerii</i> Gabb.....	×	×	×	×	×	×
<i>Cardium</i> , cf. <i>olequahensis</i> Weaver.....
<i>Cardium marysvillensis</i> Dickerson.....	×
<i>Corbicula unioides</i> (Gabb).....	×
<i>Corbula hornii</i> Gabb.....	×	×	×	×	×	×
<i>Corbula parilis</i> Gabb.....	×	×	×	×	×

¹One and one-half miles east of McCray Wells, Ventura County.

LIST OF TEJON SPECIES REPORTED IN CALIFORNIA—(Continued)

	Marysville Buttes Oroville, Ione, Merced Falls	Concord Quadrangle North of Mt. Diablo South of Mt. Diablo	Colunga District	Type Tejon	San Diego	Miscellaneous Localities	Martinez Group	Turbidolia Zone	Rimella simplex Zone	Balanophyllia Zone	Siphonalia Zone
<i>Meretrix tejonensis</i> Dickerson.....
<i>Meretrix uvasana</i> Conrad.....
<i>Meretrix gabbi</i> Arnold.....
<i>Meretrix</i> , cf. <i>olequahensis</i> Weaver.....
<i>Meretrix californiana</i> Conrad.....
<i>Modiolus ornatus</i> (Gabb).....
<i>Modiolus merriami</i> (Weaver).....
<i>Macoma</i> , sp.....
<i>Mytilus dichotomus</i> (Cooper).....
<i>Nucula cooperi</i> Dickerson.....
<i>Neaera dolabraeformis</i> Gabb.....
<i>Ostrea idriaensis</i> Gabb.....
<i>Ostrea appressa</i> Gabb.....
<i>Ostrea aviculaformis</i> Anderson.....
<i>Psammobia hornii</i> (Gabb).....
<i>Psammobia texta</i> (Gabb).....
<i>Pinna barrowsi</i> Dickerson.....
<i>Pecten interradiatus</i> Gabb.....
<i>Pecten calkinsi</i> Arnold.....
<i>Pholadidea</i> , sp.....
<i>Piacunanomia inornata</i> Gabb.....
<i>Spisula tejonensis</i> Packard.....

³Two miles east of Hacienda, New Idria District, Gabb.⁵North side of Sisar Valley, north of Astarie Oil Wells, H. W. Fairbanks.⁴Tejon of Round Valley, Mendocino County, Cal.⁶Tejon near Lower Lake, Lake County, Cal.

[illegible]⁷Benicia (?).

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LIST OF TEJON SPECIES REPORTED IN CALIFORNIA—(Continued)

	Marysville Buttes Oroville, Ione, Merced Falls	Concord Quadrangle North of Mt. Diablo South of Mt. Diablo	Coalinga District	Type Tejon	San Diego	Miscellaneous Localities	Martinez Group	Turbidolia Zone	Rimella simplex Zone	Balanophyllia Zone	Siphonalia sutterensis Zone
<i>Fusinus tumidus</i> (Gabb).....
<i>Fusinus mathewsonii</i> (Gabb).....
<i>Fusinus martinez</i> (Gabb).....
<i>Fusinus merriami</i> Dickerson.....
<i>Fusinus</i> (<i>Priscofusus</i>) <i>lineatus</i> Dickerson.....
<i>Galeodea tuberculata</i> (Gabb).....
<i>Galeodea sutterensis</i> , n. sp.....
<i>Hemifusus lewisiana</i> Weaver.....
<i>Lunatia hornii</i> Gabb.....
<i>Lunatia nuciformis</i> Gabb.....
<i>Lunatia shumardiana</i> Gabb.....
<i>Loxotrema turrita</i> Gabb.....
<i>Murex sopenahensis</i> Weaver.....
<i>Monodonta wattsi</i> Dickerson.....
<i>Mitra simplicissima</i> Cooper.....
<i>Mitra uvasana</i> Dickerson.....
<i>Mitra cretacea</i> Gabb.....
<i>Mitramorpha parsonsi</i> Dickerson.....
<i>Megistostoma striata</i> Gabb.....
<i>Metula harrisi</i> Dickerson.....
<i>Naticina obliqua</i> Gabb.....
<i>Nerita triangulata</i> Gabb.....
<i>Niso polita</i> Gabb.....

⁹Near Martinez, Tejon Group. Gabb.¹⁰Tejon Group near New Idria, Gabb.

[illegible]

RELATION OF TEJON FAUNA TO MARTINEZ FAUNA

The relation of the Tejon to the lower Eocene (the Martinez) is shown in the above table. The following species appear to be common to these two groups:

Schizaster lecontei Merriam	Dentalium stramineum Gabb
Cardium cooperii Gabb	Cypraea bayerquei Gabb
Crassatellites grandis (Gabb)	Cylichna costata Gabb
Leda gabbi Conrad	Calyptraea excentrica (Gabb)
Modiolus merriami (Weaver)	Cerithiopsis alternata Gabb
Modiolus ornatus (Gabb)	Fusinus martinez (Gabb)
Acila gabbiana, n. sp.	Fusinus mathewsonii (Gabb)
Pecten interradiatus Gabb	Lunatia hornii Gabb
Pinna barrowsi Dickerson	Niso polita Gabb
Psammobia hornii (Gabb)	Perissolax tricarnatus Weaver
Solen parallelus Gabb	Turritella conica Weaver
Marcia quadrata (Gabb)	Aturia mathewsonii Gabb
Dentalium cooperii Gabb	

The following are questionable, as some are reported by Gabb only from his "Cretaceous B" which sometimes included a portion of the Martinez.

Cuspidaria dolbraeformis Gabb	Avicula pellucida Gabb
Ostrea appressa Gabb	Lunatia nuciformis Gabb
Flabellum remondianum Gabb	

Collections made during the past two years emphasize the faunal differences between the Martinez and Tejon rather than increase their similarities. Many of the forms common to the two groups are generalized types and on this account survived through a long period of time. Thus it is apparent that the Tejon fauna was evolved in part from the Martinez and in part from other regions, particularly the Atlantic via the Panama Portal, as there are a few species common to the Gulf and Pacific Provinces. The general faunal development in the two regions during upper Eocene time is very similar. The great development of the genera *Exilia*, *Turbinolia*, *Thamnasteria*, *Turris*, *Conus*, *Natica*, *Pseudoliva*, *Cypraea*, *Rimella*, *Tellina*, *Macrocallista*, *Meretrix*, and the abundance of species representing these genera are general features which are far more characteristic of the Tejon than of the Martinez.

RELATION OF TEJON FAUNA TO THAT OF THE SAN LORENZO OLIGOCENE

As was stated above, the faunal relationship between the Tejon and Oligocene of California is not very close. *Cardium lorenzanum*

(Arnold) may be a derivative of *Cardium cooperii*, as Arnold suggested by its original name *Cardium cooperii* variety *lorenzanum*. *Aturia ziczac* Sowerby which is reported from the San Lorenzo of Santa Cruz County may be the same as *Aturia mathewsonii* Gabb. *Calyptraea excentrica* (Gabb) appears to be common to both the Tejon and San Lorenzo. A species of *Solen* which occurs in the *Agasoma gravidum* zone at Walnut Creek closely resembles *Solen parallelus* Gabb if it is not identical with it. The east of the San Lorenzo fauna of California is eocenic but any very direct connection between this Oligocene fauna and the Tejon Eocene has not been discovered. This lack of close faunal relationship seems to indicate that a time-interval of considerable duration may have occurred between the periods, or that a fauna which developed elsewhere may have entered suddenly upon the opening of a portal which had been closed during Tejon time or that both conditions as stated above may have taken place. The writer is inclined to believe that a time-interval represented by unconformity will be found although the invasion of a foreign fauna may be an element as well.

SUMMARY OF STRATIGRAPHY

Typical Tejon sections are given below and a series of columnar sections in figure 10 accompany them. The zonal divisions indicated are only approximate, as fossiliferous Tejon horizons are not present with sufficient frequency to warrant great accuracy. The broken connecting lines indicate in a diagrammatic fashion the writer's correlations between the different sections in the state. The descriptions of the sections are generalized in many cases.

Of these sections, the one north of Coalinga is probably most complete stratigraphically, but the one south of Mount Diablo exhibits the best faunal succession on the whole, and hence zonal divisions are more accurately placed. In no one place is there a section complete in all respects. Thus at Ione, Oroville and Marysville Buttes only the uppermost phase, the *Siphonalia sutterensis* zone, is represented. At San Diego and at Grapevine Creek, the type locality of the Tejon, only the *Rimella simplex* zone is present. The upper Eocene in the Santa Ana Mountains is probably but a residual of the same zone. Another residual occurs in northern California near Lower Lake and it probably represents portions of the *Rimella simplex* and *Balanophyllia variabilis* zones.

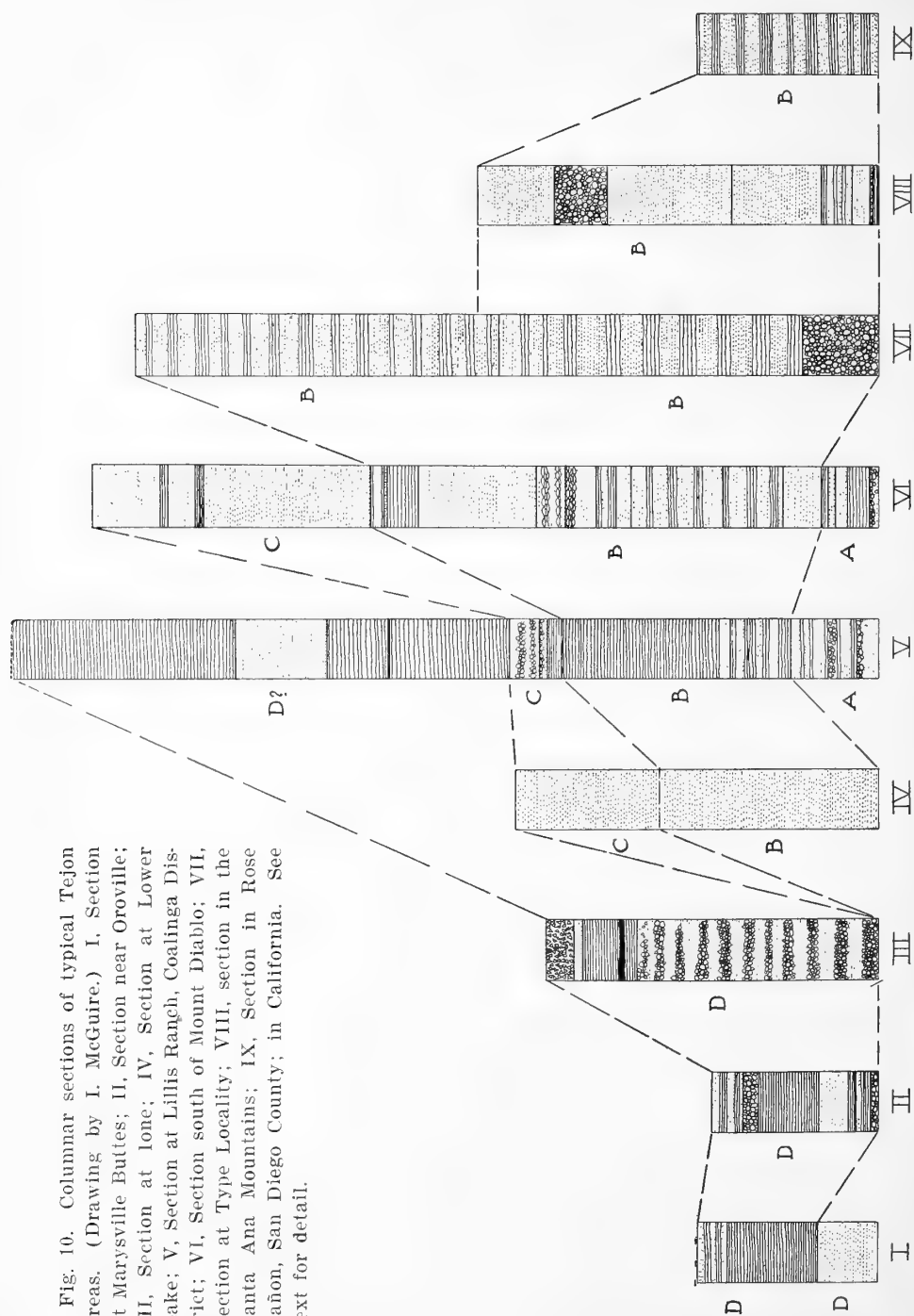


Fig. 10. Columnar sections of typical Tejon areas. (Drawing by I. McGuire.) I, Section at Marysville Buttes; II, Section near Oroville; III, Section at Lone; IV, Section at Lower Lake; V, Section at Lillis Ranch, Coalinga District; VI, Section south of Mount Diablo; VII, Section at Type Locality; VIII, section in the Santa Ana Mountains; IX, Section in Rose Cañon, San Diego County; in California. See text for detail.

I. SECTION AT MARYSVILLE BUTTES, CALIFORNIA

			feet
Tejon Eocene	{	D {	(3) Green-gray sandstones and shales with limestone concretions marking the upper limit of the Eocene 100
			(2) Green-gray, glauconitic shale 300
			(1) Massive thin-bedded buff sandstone resting upon Chico sandstone and limestone..... 200
			<hr/>
			Total..... 600

II. SECTION NEAR OROVILLE, CALIFORNIA

Tejon Eocene	{	D {	(9) Older basalt	100-150
			(8) Andesitic tuff-breccia	10-20
			(7) Alternating sandstone, clay and carbonaceous shales	100
			(6) Conglomerate	50
			(5) Tuffaceous clay	200
			(4) Yellow tan sandstone	100
			(3) Dark gray shales interbedded with lignite con- taining fossiliferous strata and thin-bedded fos- siliferous sandstone	40
			(2) Clay with tuff fragments	20
			(1) Conglomerate resting upon Chico sandstone.....	20
Total.....			530	

III. SECTION AT IONE, CALIFORNIA

Tejon Eocene	{	D {	(5) Andesitic tuff-breccia.....	
			(4) Light gray clay rock, an altered rhyolitic tuff.....	90
			(3) White or red sandstone.....	30
			(2) Rhyolitic tuff altered to a clay containing a seam of coal	180
			(1) Conglomerate and sandstone.....	800
			<hr/>	
			Total.....	1100

IV. SECTION AT LOWER LAKE, CALIFORNIA

Tejon Eocene	{	C B {	(1) Coarse gray to white conglomeritic concretionary sandstone 1200
			<hr/>
Martinez Eocene	{		Thin-bedded, fine-grained, green-gray sandstone
			<hr/>
			Total..... 1200

V. *SECTION OF TEJON EOCENE, LILLIS RANCH, COALINGA DISTRICT

			feet
Oligocene	{	(10) White shale White fossil organic shales, containing fish scales, teeth, foraminifera, etc. ....500 Lenses of fine brown sand	
Tejon Eocene?	{	(9) White shales with local thin sandy strata.....	1000
	{ D?	(8) Local friable sand.....	300
		(7) Pink to white shale.....	200
		(6) Bluish sandy shales grading up into pink shales....	400
	{ C	(5) White sandstone and conglomerate.....	100-160
		(4) White massive sandstone and conglomerate with whitish shale inclusions at the base.....	20-40
Tejon Eocene	{ B	(3) Upper chocolate shales, comprising bluish shales at top, grading down into chocolate or brown shales which weather to clays. These rest upon other chocolate shales which become sandier to- ward bottom. These shales vary in thickness..	600-900
		(2) Yellow sand and conglomerate Bluish sandy shales and thin sandstone, vari- able in thickness	200
	{ A	(1) Massive yellow sandstone with large dark brown segregations and concretions and some layers of bluish sandy shale. Fine sand with local beds of conglomerate inter- bedded with blue and brown shales, a consider- able amount of glauconitic material at base.....	300
Chico Cretaceous	{	Lower chocolate shales Beds of chocolate and brown shales with small ferruginous and limy concretions and layers of glauconitic sand	1000
Total.....			3120

* Modified from Dumble's section.

VI. SECTION OF THE TEJON GROUP SOUTH OF MOUNT DIABLO

Chico sandstone and limestone

		feet
Tejon Eocene	C	(22) Massive tan sandstone..... 225
		(21) Blue shale 25
		(20) Massive tan sandstone..... 85
		(19) Carbonaceous shales and lignite..... 25
		(18) Massive tan sandstone, third bluff..... 554
	B	(17) Carbonaceous shale and thin-bedded sandstone.... 45
		(16) Light gray sandstone 8
		(15) Shale 100
		(14) Massive tan sandstone, second bluff..... 390
		(13) Massive soft sandstone with <i>Turritella uvasana</i> beds, second bluff 100
		(12) Thin-bedded sandstone with <i>Turritella uvasana</i> beds on top 100
		(11) Shale with thin-bedded sandstone..... 63
		(10) Thin-bedded sandstone 50
		(9) Sandstones with interbedded shales..... 307
		(8) Alternating soft sandstones and carbonaceous shales 200
		(7) Light tan coarse sandstone with cavernous weathering, first bluff 125
	A	(6) Gray-green foraminiferal shale 25
		(5) Massive tan sandstone 20
		(4) Hard gray sandstone 40
		(3) Gray foraminiferal shale 75
		(2, 1) Conglomerate and thin-bedded sandstone..... 25
Total.....		2587

VII. SECTION OF TEJON AT TYPE LOCALITY

Tejon Eocene	B	(3) Light tan sandstone and shale..... 1200
		(2) Thin-bedded brown sandstone with shale..... 1000-1200
		(1) Coarse conglomerate composed of granitic rocks resting on granite, basal member..... 250-300
		Total..... 2450

VIII. SECTION IN THE SANTA ANA MOUNTAINS

Tejon Eocene	B	(8) Fine-grained light tan sandstone containing an abundance of fish scales..... 250
		(7) Coarse conglomerate 170
		(6) Massive white sandstone..... 400
		(5) Massive white and gray, medium-grained to fine soft-weathering sandstone 300
		(4) Shale and thin-bedded sandstone..... 105
		(3) Medium-grained gray sandstone 85
		(2) Fossiliferous limestone 2
		(1) Lignite and carbonaceous shale..... 12
		Total..... 1324

IX. SECTION IN ROSE CAÑON, SAN DIEGO COUNTY			feet
Tejon	{	B {	Alternating beds of shale, white sandstone resting on Chico
Eocene			600

AREAL DISTRIBUTION OF TEJON GROUP

The Tejon has a much greater distribution than the Martinez, which as far as known is confined to the San Francisco and Los Angeles basins, small negative areas in the vicinity of these two California cities. (See figures 11, 12, 13, 14.) No Martinez has been reported from Oregon, Washington, or British Columbia, but the Tejon group is represented by immensely thick beds in Oregon and Washington and it is also found on Vancouver Island, as good specimens of *Turritella uvasana* were collected by Professor Lawson from tuffs interbedded with lava flows. The southernmost occurrence of the Tejon is at San Diego. Tejon has been reported from Lower California at 29° 30' N. latitude but the few fossils reported from there are Martinez forms. Tejon is reported from Round Valley, Mendocino County by Gabb.⁷⁸

Just what stage is represented is unknown, but the writer is inclined to think that it may be the Rimella simplex zone, as Gabb, who knew the fauna of the type Tejon, said that there were several typical Tejon forms present. The Tejon near Lower Lake is but a residual and it has thus far yielded but a small fauna which has been placed doubtfully as belonging to the third zone of the Tejon, the Balanophyllia variabilis zone.

The Ione facies of the Tejon group is found at several places in the Redding quadrangle and it appears to underlie most of the country covered by later tuffs and lavas. This uppermost phase of the Tejon Eocene, the Ione, has yielded the Siphonalia sutterensis fauna. In the upper Sacramento Valley on both the west and east sides as well as the north end, the Ione is but gently inclined. Dips of but 1° or 2° are usual in the littoral deposits beneath the basalt of Oroville South Table Mountain. A similar condition is found along the eastern border of the Great Valley. At Marysville Buttes the off-shore phase of the Siphonalia sutterensis zone is found in deposits which dip in all directions from the andesitic stump of this ancient volcano. The Tejon of Lower Lake, which is about west of the Marysville Buttes, is gently folded in the syncline near Lower Lake in marked contrast

⁷⁸ Gabb, W. M., Geol. Surv. Cal. Palaeontology, vol. 2 (preface, p. 13), 1869.

to low dips of the Ione of the north Sacramento Valley. Evidently folding and faulting in post-Ione time in the Coast Ranges has been quite vigorous in contrast to the slight changes in the Klamath Province.

As will be shown later, the physiographic provinces of California were inaugurated in Eocene time and a part of the diastrophic movements which have determined these provinces actually took place during the Eocene.

Diller⁷⁹ recognized the Ione formation on the west side of the Sacramento Valley in the vicinity of the Cold Fork of Cottonwood Creek, Tehama County.

On Cold Fork, however, only a few miles further north, the exposures are good and thirty feet of the Ione formation was seen. It is composed chiefly of yellow gravel, but is separated from the overlying tuff by a stratum of clay about a foot in thickness. Here the Ione formation ends abruptly against a steep slope of the Cretaceous strata upon the edge of the base level of erosion, but the overlying tuff and Red Bluff formation lap over upon the base level, showing that they are of later origin.

On Salt Creek, about six miles north of Cold Fork, the Ione formation has the largest exposure seen on the western side of the Sacramento Valley. Immediately beneath the tuff there is sixteen feet of clay, which is underlain by forty-eight feet of sand and gravel beds, making a total thickness of sixty-four feet exposed. The gravel predominates and the pebbles increase in size toward the base. Similar sections are seen in Dry Creek, Roaring River, and the North Fork of Cottonwood Creek. In every case the bed lying immediately beneath the tuff is a layer of clay. This top bed of clay extends further westward upon the edge of the base level than any of the other beds, and the whole formation rapidly increases in thickness toward the Sacramento Valley. In some cases the tuff and gravels of the Red Bluff formation lap over upon the base level plain for several miles, but the Ione formation stops at its edge.

Judging from Diller's description, the shore line of the Eocene sea was marked by these deposits along the edge of the Klamath penepplain. The occurrence of marine Ione at Oroville and at Marysville Buttes has been described in detail above. It seems probable that there was not an extensive land-mass west of the Marysville Buttes, as the Eocene deposits in this vicinity were laid down in water about one hundred fathoms in depth along the edge of the continental shelf, as is evidenced by the abundance of glauconite and by certain deep-water facies exhibited by the fauna.

South from Oroville unmistakable strand-line conditions have been recognized at Ione, Merced Falls and Bear Creek, Merced

⁷⁹ Diller, J. S., *Topographic Revolution on the Pacific Coast*, Fourteenth Annual Report U. S. Geological Survey, p. 455, 1894.

County, as were described above. Whitney⁸⁰ describes the region further south as follows:

From Kern River to Kings River, the metamorphic and granitic rocks continue into the valley until covered by the recent detritus; but north of Kings River, as far as the Stanislaus, there is a belt of low flat-topped and dome-shaped hills of sandstone, rising one hundred to one hundred and fifty feet above the level of the plain. A little north of the Merced River, to the west of the road from Bear Valley to Stockton, a very handsome variety of sandstone was observed, forming low cliffs near the summit of a hill about one hundred and fifty feet high. This rock was a fine-grained free-stone, elegantly ornamented with fine, waving and concentric lines and bands of a light rose-red color. For some kinds of architectural purposes, this stone would be a very desirable material.

Such is the basis for the strand line to Kings River on the eastern side of San Joaquin Valley.

Large collections from the type locality of the Tejon group made by Mr. Bruce Martin of the California Academy of Sciences and by the writer, do not contain the *Siphonalia sutterensis* fauna. Mr. Clark Gester reports much thicker beds of Tejon north of the Cañada de las Uvas in the vicinity of San Emigdio Creek and certain white shales in this vicinity may represent the equivalent of the *Siphonalia sutterensis* zone.

Mr. John Ruckman found *Trochocyathus*, cf. *striatus* (Gabb) and *Crassatellites* (*Astarte*) *mathewsonii* (Gabb) in white shale beds immediately overlying the white Tejon sandstone in the Coalinga district near Domengine Creek. The coral is not definitely determinable, but it resembles *Trochocyathus striatus*, a characteristic form of the Tejon. The shales are somewhat ashy and they may represent reworked rhyolitic ash of the Sierra Nevada. The upper portion of these beds yielded Mr. Ruckman a small but characteristic fauna of Oligocene age, San Lorenzo stage. The Tejon fauna below the white shale is about the equivalent of the *Balanophyllia* zone, Mount Diablo region, which is between that of the type Tejon and the *Siphonalia sutterensis* fauna. No other localities in which the uppermost zone of the Tejon is found are known in the Coast Ranges of California. Some residuals may yet be found, but apparently the uppermost strata of the Tejon were removed at least in large part during the great intervals of erosion between the Eocene and Oligocene, and Oligocene and Miocene. According to Fairbanks,⁸¹ no Tejon was deposited within

⁸⁰ Whitney, J. D., Geological Survey of California, Geology, vol. 1, p. 202, 1865.

⁸¹ Fairbanks, H. W., San Luis Folio, No. 101, U. S. Geological Survey, p. 3, 1904.

the area of the San Luis Quadrangle and he states that the area was probably an insular mass during Eocene time. No Eocene is reported from the San Juan district in southeastern San Luis Obispo County.

The coal of the Stone Cañon area in the southeastern corner of Monterey County is Miocene in age and not Eocene. Eocene deposits are lacking in this area and in the rest of the Priest Valley Quadrangle to the north. So far as known, Monterey County does not contain deposits of this age within its borders.

South of the San Luis Quadrangle, great thicknesses of Eocene strata which are at least in part Tejon were reported by Eldridge.⁸²

Lawson⁸³ mapped no Tejon in the Mount Tamalpais Quadrangle. No Tejon has been reported from Sonoma County.

The Tejon occupies quite extensive areas in Napa and Solano counties and the three lower zones are probably all represented. Just south, in the Concord Quadrangle, the Tejon has a thickness of about 2000 feet. The lowermost zone, the *Turbinolia* zone, and the second, the *Rimella simplex* zone, are present. The third zone, the *Balanophyllia variabilis* zone, may be represented by the non-fossiliferous beds at the top of the Tejon in this vicinity. The *Turbinolia*, the *Rimella simplex*, and the *Balanophyllia variabilis* zones have their type localities in the area south of Mount Diablo. The uppermost, or *Siphonalia sutterensis* zone, appears to be entirely absent in the San Francisco Bay region. The reason for this will be discussed later.

The Ione phase of the upper Eocene is found along the eastern side of the Great Valley from Oroville to Fresno River but the other zones are missing here. On the western side of the Great Valley, Tejon is found at frequent intervals from Mount Diablo to the Tehachapi Mountains. At least three zones of the Tejon are present in the Temblor Mountains in the Coalinga District and possibly the uppermost may be represented by a portion of the white shales in the oil fields of Coalinga. At the type locality of the Tejon in the Tehachapi Mountains only the *Rimella simplex* zone is present.

Along the coast from Mendocino County to southern San Luis Obispo County, no Tejon has been reported, but the non-fossiliferous Butano formation of the Santa Cruz Quadrangle may belong to this group. West and south of the type locality of the Tejon, however,

⁸² Eldridge, G. H., and Arnold, R., The Santa Clara Valley, Puente Hill, and Los Angeles Oil District, Southern California, Bull. No. 308, U. S. Geological Survey, pp. 5-7, 1907.

⁸³ Lawson, A. C., San Francisco Folio, No. 193, U. S. Geological Survey, 1914.

extensive deposits of Tejon strata are found in the Santa Maria and Santa Clara Valley oil districts. Tejon is reported from the Calabasas Quadrangle a few miles northwest of Los Angeles. The faunal stages represented here are somewhat doubtful but intensive study in this field will probably show the presence of a very complete faunal sequence. From a cursory examination of faunas from this region, the *Turbinolia* and *Rimella simplex* zones appear to be represented.

Tejon Eocene appears to be present on Tully's Ranch on Bitterwater Creek, San Benito County, according to the work of the geological staff of the Union Oil Company. This locality is only a few miles north of Stone Cañon and is probably a residual.

The reconnaissance work thus far done in the Santa Lucia Range in western Monterey County has not resulted in the discovery of any rocks of Eocene age. Lawson reported the Carmelo series as questionably Eocene, but he is not inclined to this opinion now.

The small outliers of the Tejon in the Santa Ana Mountains and the gently dipping sandstones of the San Diego Eocene represent the *Rimella simplex* zone. Such in brief is the known distribution of the beds of the Tejon group in California.

The absence of the Tejon group from the outer Coast ranges of California from Cape Mendocino to the Santa Maria River in Ventura County is very remarkable. Two explanations are possible: (1) the Tejon was never deposited over the site of the outer ranges such as the Santa Cruz Mountains and the Santa Lucia Range, but the upper Eocene sediments were deposited in a great sound which opened widely to the south, (2) the Tejon was deposited by a transgressing sea and its sediments were removed in post-Tejon time. Lawson⁸⁴ has discussed these two hypotheses for the San Francisco Bay region in connection with the deposition of the Miocene as follows:

In the Bear Creek anticline, in the northwestern part of the Concord Quadrangle, the lower Monterey strata rest upon the Tejon, but here the structure of the Tejon is so obscure that it is not possible to discover whether or not there is structural discordance, and no conglomerate has been observed at the base of the Monterey. The consideration of these three sections thus affords evidence of no very profound degradation of the Tejon in the pre-Monterey interval of uplift.

In the section exposed in the Berkeley Hills, however, about five miles southwest of the Bear Creek anticline, the Monterey rock rests directly upon the Chico. Both Tejon and Martinez are absent. The Claremont shale, the second formation of the Monterey group, lies almost in direct

⁸⁴ Lawson, A. C., The San Francisco Folio, U. S. Geol. Surv. Folio 193, p. 10, 1914.

contact with the Chico, the Sobrante or basal sandstone of the Monterey group being represented by only a thin layer of yellow incoherent sandstone, mapped with the Claremont. There are no conglomerate beds at the base of the Monterey in this section, for here the Eocene rocks, which are more than 4000 feet thick 9 or 10 miles farther northeast, either were not deposited or, as seems more probable, had been completely removed in pre-Monterey time. One justification for the view that the Eocene rocks once extended over the region of the Berkeley Hills and were removed in the Eocene-Miocene interval is that this part of the Coast Ranges contains no representative of the San Lorenzo formation (Oligocene), which occurs to the thickness of 2500 feet in the Santa Cruz Quadrangle. In San Lorenzo time the Berkeley Hills region was probably a zone of erosion.

The fifth section in which the Monterey is exposed in superposition upon older rocks is at Selby, on San Pablo Bay, in the Napa Quadrangle a few miles north of the San Francisco Quadrangle, where a well-defined unconformity is revealed in a cliff. The surface upon which the Monterey rocks rest is a wave-cut terrace, perforated by many holes made by boring molluscs. The strata in which this terrace is cut are soft black shales, which are probably Martinez in age, for Martinez fossils have been found in the sandstones that adjoin them on the north. These shales have a southerly dip of about 70°, and the surface of the perforated terrace and the superimposed sandstones of the Monterey dip in the same direction at about 60°. It is evident that the shales were elevated above sea-level and inclined at about 10° to the horizon when they were truncated to form the terrace. The sandstone of the Monterey contains a fossil fauna which, in the opinion of Professor J. C. Merriam, is that of the middle Monterey. The Tejon is apparently absent here, although it is abundantly represented only a few miles to the southeast, along the strike of the rocks. The Monterey sea evidently did not extend over this part of the region until middle Monterey time, and therefore part of the erosion is referable to early Monterey time. In general, however, the historical facts that are so clearly manifest at Selby are consistent with and support the interpretation of the section in the Berkeley Hills, where the Monterey rests directly upon the Chico.

The middle Miocene, *Turritella ocoyana* zone, in the vicinity of Stone Cañon in Monterey County rests directly upon the Franciscan and upon remnants of Chico without any intervening Eocene strata. This region is west of the Coalinga District where the Tejon is fairly well exposed. Fairbanks⁸⁵ reported no Eocene in the San Luis Quadrangle, but the Miocene rests upon granite, Franciscan, Knoxville or Chico indifferently. He described conditions as follows:

With the close of the Cretaceous and the advent of the Tertiary a marked change took place. The region of the Coast Ranges began to rise and the ocean was excluded from the greater portion of it. The water continued, however, to occupy Sacramento and San Joaquin Valleys, maintaining an outlet to the south across Ventura and eastern

⁸⁵ Fairbanks, H. W., San Luis Folio, U. S. Geol. Surv. Folio No. 101, p. 9, 1904.

Santa Barbara Counties. This view is based upon the fact that within the San Luis Quadrangle, as well as northwestward through the heart of the Coast Ranges, the Eocene, or Tejon formation, is entirely absent, while on the borders of the Great Valley and southward across the Coast Ranges the formation is extensively developed. The Eocene, then, in the region under discussion was an epoch of erosion, and it was during this time that large portions of the earlier formations were removed. The region was probably reduced to one of low relief, and the waste material was deposited beyond the present shore line.

Decisive direct evidence upon this question can be obtained only by careful mapping of large areas. In the vicinity of Stone Cañon, Monterey County, the areal and structural relations of the Miocene to the Franciscan and Cretaceous indicate a very great period of erosion between the deposition of the Chico-Cretaceous and the Miocene sediments. This is shown by the residual nature of the Chico exposures in many places and by pre-Miocene folding.

The fauna of the Tejon in the Coalinga District which is east of the San Luis Quadrangle contains such genera as *Spatangus*, *Trochocyathus*, *Balanophyllia*, *Turbinolia*, *Spisula*, *Turris*, *Fusus* and *Surcula*, in abundance. These genera are more characteristic of an archipelago or open-ocean habitat than that of a sound. Such genera as *Barbatia*, *Potamides* and *Corbicula* do occur, but in most cases strata containing such an assemblage are limited in extent and probably represent estuarine deposits near the mouths of the Eocene rivers.

Rocks derived from the Franciscan, Chico, and Martinez groups form the conglomerate boulders in the basal Tejon member north of Mount Diablo. Their occurrence suggests the existence of a continental land-mass a short distance east of the present site of Mount Diablo or of islands in this vicinity. The absence in this region of uppermost Tejon sediments, their presence forty miles eastward, and the direct field evidence in the Ione facies of the Tejon Eocene which demonstrates deposition along a shore line by a transgressing sea can be easily explained by a great interval of erosion in post-Eocene time during which all the Tejon sediments were removed from the outer ranges and the uppermost sediments from the inner of the Coast Range. An unconformity between the Oligocene and the Tejon at Walnut Creek indicates that this condition existed, for the uppermost Tejon strata contributed coal and sandstone to the basal conglomerates of the Oligocene. The Tejon was possibly exposed to subaerial erosion during another long period of time which in certain places is

represented by unconformity between the Miocene and Cretaceous. Both time-intervals were apparently very long ones. They were so long that but few Tejon species persisted into the Oligocene, and none into the Miocene. When one remembers that the Tejon fauna contains at least 300 to 400 mollusca, the length of time represented by these two unconformities is quite sufficient to account for the removal of the Tejon by erosion from the present sites of the mountains bordering the Pacific. The distribution of Tejon sediments, the absence of the *Siphonalia sutterensis* zone in the Mount Diablo region, the presence of a typical marine fauna in most horizons of the Tejon and the existence of two periods of erosion between the Tejon and Miocene, lead to the conclusions that the Tejon was deposited by a transgressing sea and that Tejon sediments were largely removed from the outer Coast Ranges during post-Tejon and pre-Miocene time. The existence of islands upon a wide continental shelf is possible, but if they existed they were not sufficient in number or extent to prevent the free access of the Eocene ocean.

GEOGRAPHY OF THE TEJON SEA

During the whole of Eocene time in California the San Francisco Basin⁸⁶ was a negative area, and for this reason the Eocene record of deposition is most complete in this portion of California. This basin was small during Martinez time, being merely an open bight extending from the vicinity of Lower Lake in Lake County to about the southern boundary of San Mateo County. The most easterly point in the basin in Martinez time was probably a few miles east of Benicia. After the recession of the sea at the close of Martinez time, mountain-making movements were moderately active and the Martinez strata were folded and eroded. Again, the San Francisco Basin was an area of sedimentation at the beginning of Tejon time. Apparently the Eocene sea during early Tejon time transgressed upon the land in the San Francisco Basin to a far greater extent than during Martinez time. The Tejon sea probably extended from the vicinity of Round Valley, Mendocino County, to the vicinity of Coalinga. The data upon which this is based was given above. During Tejon time, numerous local oscillations occurred. The sedimentary record on the north and south sides of Mount

⁸⁶ Dickerson, R. E., *Fauna of the Martinez Eocene of California*, Univ. Calif. Publ. Bull. Dept. Geol., vol. 8, No. 6, pp. 69-71, 1914.

Diablo and in the vicinity of Coalinga register these oscillations by local unconformities, which indicate a fluctuating condition of the strand line, the major movements being those of subsidence. Apparently this subsidence continued and the consequent transgression of the sea caused the sediments which contain the *Siphonalia suterensis* fauna to be laid down upon the western foothills of the Sierra Nevada.

The Los Angeles Basin during Eocene time appears to have undergone movements quite different from those in the San Francisco Basin. So far as known, the Tejon sea did not extend as far eastward as the Martinez sea and only the middle portion of the Tejon was deposited along a strand line which extended only five to ten miles east of the present coast. The Tejon fauna of San Diego County represents only the middle zone, both the lowermost and uppermost zones being lacking. It seems very doubtful if either was ever present. Orogenic movements have not been as vigorous in Southern California since the deposition of the Tejon as in Northern California, since the beds at San Diego and in the Santa Ana Mountains are but slightly inclined. In brief, the movements in the two basins were just opposite, the Martinez exhibiting the greater subsidence in the Los Angeles Basin, the Tejon in the San Francisco Basin.

The presence of islands is suggested by Fairbank's work. A wide channel probably connected the Tejon Eocene of the San Joaquin Valley with that of the Santa Clara Valley of the south. These islands were probably somewhat similar to the Channel Islands of southern California. No large land-locked bays appear to have been present in the southern portion of the San Francisco Basin during Tejon time, as the marine faunas are not, broadly speaking, estuarine but those of a more open coast. Coal seams, however, do occur locally at several horizons in the Tejon with an associated estuarine fauna. They probably represent sedimentation at the mouths of large rivers which flowed westward from the Eocene Sierra Nevada.

The earliest sediments of the Tejon Eocene were deposited in an enlarged, elongated San Francisco Basin (see figure 11). The northern extent of this area of deposition is doubtful, but it probably extended as far north as Mendocino County. The *Turbinolia* zone is typically represented south of Mount Diablo and it also occurs in the vicinity of Coalinga. It is probably represented in Santa Barbara County at the base of the so-called Topatopa formation.



Fig. 11. Map of California showing probable extent of the Tejon Sea during the deposition of the rocks containing the *Turbinolia* fauna.



Fig. 12. Map of California showing probable extent of the Tejon Sea during the deposition of the rocks containing the *Rimella simplex* fauna.

Without any marked change in deposition and without any apparent unconformity between the *Turbinolia* Zone and the *Rimella simplex* Zone, the sediments containing the *Rimella simplex* fauna were laid down on top of the earlier sediments in the San Francisco Basin. By gradual enlargement of the San Francisco Basin through sinking and the consequent transgression of the Tejon sea, the shore line was extended in this basin further east, further north and further south across the present site of Cañada de las Uvas, the type locality of the Tejon. At this time the Los Angeles Basin again became an area of deposition as is shown by the Tejon sandstones of the Santa Ana Mountains and of San Diego County (see figure 12). The deposition during this period was probably interrupted by slight uplifts followed by slight depressions and the shore line was a decidedly shifting one as is indicated by slight, local unconformities south of Mount Diablo and by the alternations of estuarine and marine faunas.

Apparently the Los Angeles Basin did not remain beneath the sea during the deposition of the rocks containing the two succeeding faunas, as the *Rimella simplex* fauna is the only one represented there. The *Balanophyllia* zone is typically represented in the Mount Diablo region, and probably occurs in the vicinity of Lower Lake as well. The fauna from the top of the white sandstone member of the Tejon north of Coalinga represents this zone. Apparently the present site of the Tehachapi Mountains was a land-mass at this time. Land conditions probably extended for fifty miles further north, shutting out the Tejon sea from the vicinity of the type Tejon.

The San Francisco Basin was still further lowered to receive the sediments containing the *Siphonalia sutterensis* fauna and the advancing shore line of the transgressing Tejon sea moved farther and farther to the eastward and the golden sands of the earlier gravel period and the rhyolitic tuffs were deposited across the truncate edges of the Mariposa slates and associated intrusives of the Bedrock series. Far to the north between the Klamath and the Sierra Nevada a great bay extended and estuarine deposits were laid down across the present site of the town of Redding. Into this bay and the Tejon-Pacific Ocean the rivers of the Klamath Mountains and Sierra Nevada plunged rapidly, bringing with their waters the sands and gravels. According to Diller, the Klamath Province was a peneplain at this time and according to Lindgren the Sierra Nevada region had advanced in topographic development to middle or late maturity with



Fig. 13. Map of California showing probable extent of the Tejon Sea during the deposition of the rocks containing the *Balanophyllia* fauna.



Fig. 14. Map of California showing probable extent of the Ione-Eocene Sea.

1. Tejon of Round Valley, Mendocino County; 2. Ione-Eocene, Cold Fork of Cottonwood Creek, Tehama County; 3. Ione-Eocene, near Oroville; 4. Ione-Eocene of Marysville Buttes; 5. Ione-Eocene at Ione, Amador County; 6. Ione-Eocene near Merced Falls; 7. Ione-Eocene near Kings River; 8. Tejon group at Lower Lake, Lake County; 9. Tejon group, vicinity of Mount Diablo; 10. Tejon group, Coalinga District; 11. Stone Cañon, Monterey County, Cal.; Eocene, absent; 12. San Luis Obispo County; Eocene, absent; 13. San Juan District, San Luis Obispo County; 14. Tejon group, San Emigdio Creek; 15. Tejon group near Lompoc, Cal.

crest line mountains of 3000 to 5000 feet. These mountains and the numerous moderately wide valleys of short, consequent westward-flowing streams were covered by great forests of subtropical plants in the lowlands and coniferous forests along the crest of the Eocene Sierra Nevada. Remains of these plants have accumulated in sufficient quantity to form a 12-foot seam of Ione coal. During this period great rhyolitic ash and mud flows changed the whole appearance of the western Sierra Nevada, filling the valleys to their brims and vastly altering the drainage.

This great rhyolitic period was interrupted long enough for the development of new drainage systems as represented by the inter-rhyolitic channels and their correlative marine Ione sandstones. After this, a period of erosion ensued and then the andesitic tuffs, lavas and mud flows covered all, extending even beyond the border of the eastern edge of the Great Valley as is shown at Lincoln, Sacramento County. Basalt of approximately the same age as the andesite capped the Eocene deposits in places. This great thickness of lavas formed a protective coating and preserved the latest Tejon, the Ione, from erosion along the eastern border of the Great Valley. In the Coast Ranges farther to the west, the sediments containing the *Siphonalia sutterensis* fauna were probably not so thick, for they were laid down in deeper water and in general lacked a protective lava capping. Hence their rapid disappearance over most of this area.

CORRELATION

HISTORICAL

The correlation of the Tejon with the Claiborne Eocene of the Gulf States was suggested by Conrad upon his first examination of the fossiliferous boulder from Cañada de las Uvas which was sent by Blake. Dall, Heilprin, Clark, Harris, and Arnold have all made tentative correlations. Most of these have been based upon the identity of a few species and the recognition of equivalent faunal development.

Conrad⁸⁷ reported *Natica aetites*, *Natica gibbosa*, *Venericardia planicosta*, *Crassatella alta*, of the Claiborne Eocene as being present in the Tejon of the type locality. None of these is strictly identical with the corresponding Tejon form.

⁸⁷ Conrad, T. A., Pacific Railroad Reports, App. to Prelim. Geol. Rept. of W. P. Blake, Palaeontology, pp. 5-20, 1855.

Heilprin⁸⁸ was the next writer to point out faunal similarities. He compared *Cardita planicosta* Gabb with the typical *V. planicosta* and agreed with Gabb that there was a difference in the shape of the ribs. "*Dosinia elevata* Gabb appears to be very closely allied to the *Dosiniopsis meeki* of Conrad of the lower Eocene of Maryland and Virginia." "*Meretrix hornii*, a form allied to, but not as produced posteriorly as the *Cytherea suberycinoides* of the Paris basins." *Tritonium paucivaricatum* is, according to Heilprin, a *Cancellaria* which is "a form so closely related to *C. evulsa* of Brander from the British Bartonian (upper Eocene), that it may well be doubted that it is at all specifically distinct". *Megistostoma striata*, according to Heilprin, exhibits no characters which will distinguish it from *Bulla laea expansa* Dixon of the Eocene of Brackelsham, England, and the Paris Basin.

Harris⁸⁹ was the next investigator to compare representative species of the West Coast and the East Coast Eocene. He says:

While comparing the Texas Eocene fossils with type specimens and others in the collection of the U. S. National Museum and in the Philadelphia Academy of Natural Sciences, I have been impressed with the remarkable sameness in the faunal characters throughout the vast extent of the lower Claiborne or Lisbon horizon; many of the species from South Carolina are identical with those from the banks of the Rio Grande, and the rocks from Fort Tejon, California, furnish a very similar fauna with several identical and many analogous species. Gabb's *Cardita hornii* is *Venericardia planicosta* Lam., as held by Conrad; the type specimen is slightly malformed and imperfect but others from the same locality are quite typical *V. planicosta*. Gabb's *Architectonica cognata* is Conrad's *Solarium alveatum*; Gabb's *Architectonica hornii*, Conrad's *Solarium amoenium*; Gabb's *Neverita secta*, Conrad's *Natica aetites*, and so on. Gabb's peculiar and characteristic little *Whitneya ficus* is known from Alum Creek Bluff, Colorado River, Bastrop County, Texas and is in itself a strong argument for the synchrony of the Texas and California beds from which it is derived. Moreover in deposits of this horizon on both sides of the Rockies there are similar developments in the genera *Crasatella*, *Cytherea*, *Pyrula*, *Levifusus*, *Rimella*, and others.

With the above facts in mind I can not help suggesting that those who have an opportunity to study the Eocene series of California (Tejon deposits) would do well to look for the Midway stage which ranks second in persistency among the subdivisions of the Eocene along the Gulf Slope. In other words, search should be made along the Chico-Tejon contact for such species as *Enclimatoceras ulricii*, *Oculllaia macrodonta*, *Ostrea pulaskensis*, together with varieties of *Venericardia planicosta*, *Turritella mortoni*, *T. humerosa* and other Midway forms.

⁸⁸ Heilprin, A., Proc. Acad. Nat. Sci. Philadelphia, vol. 34, pp. 196-214, 1882.

⁸⁹ Harris, Correlation of the Tejon with Eocene Stages of the Gulf Slope, Science, vol. 22, p. 97, Aug. 18, 1893.

From all evidence it seems likely that the Tejon series is the correlative of the Claiborne at least in part.

All of these writers examined material which was principally derived from the Tejon of Cañada de las Uvas and hence their comparisons are chiefly valuable as respects the position of the Rimella simplex Zone of California.

SPECIES COMMON TO THE GULF AND PACIFIC PROVINCES

The number of identical species between the Tejon Eocene and the Eocene of the Gulf is much smaller than the writer first supposed. Many of the forms which at first sight appear to be identical reveal slight differences when directly compared. These differences are in general of specific or subspecific value at least. The general faunal development in the Tejon is so similar to that of the Gulf Province that one is easily deceived into thinking that the specific characters are also alike.

A tabular comparison between identical or congeneric species of the Gulf Province and the Tejon is given below.

Midway		Tejon
<i>Exilia pergracilis</i> Conrad	=	<i>Exilia dickersoni</i> (Weaver)
<i>Natica eminula</i> Conrad	=	<i>Neverita secta</i> Gabb
<i>Protocardia nicolletti</i> Conrad	cf.	<i>Cardium marysvillensis</i>
<i>Natica perspecta</i> Whitfield	cf.	<i>Natica nuciformis</i>
Lignitic		
(Wilcox formation)		
<i>Philene alabamensis</i> Aldrich	=	<i>Megistostoma striata</i> Gabb
<i>Modiolus alabamensis</i> Aldrich	=	<i>Modiolus ornatus</i> (Gabb)
<i>Pleurotoma mediavia equisetæ</i>		
Harris	=	<i>Turris inconstans</i> (Cooper)
<i>Pleurotoma denticula</i> Harris	=	<i>Turris stocki</i> , n.sp.
<i>Cypræa smithi</i> Aldrich	=	<i>C. mathewsonii</i> Gabb
<i>Natica eminula</i> Conrad	=	<i>Neverita secta</i> Gabb
<i>Calyptraea aperta</i> Sol.	=	<i>C. excentrica</i> (Gabb)
<i>Venericardia planicosta regia</i>		
Rogers	=	<i>V. planicosta hornii</i> Gabb
<i>Venericardia planicosta</i> var.		
Harris	=	<i>V. planicosta merriami</i> Dick.
<i>Ancillaria staminea</i> Conrad	cf.	<i>Olivula marysvillensis</i> Dick.
<i>Metula sylvaerupis</i> Harris	cf.	<i>M. harrisi</i> , n.sp.
<i>Ficopsis penita</i> Conrad	cf.	<i>F. remondii</i> (Gabb)
<i>Pleurotoma roscoeii</i> Harris	cf.	<i>Drillia cooperi</i> , n.sp.
<i>Cadulus abruptus</i> Ald. and Meyer		
Claiborne	=	<i>Cadulus pusillus</i> (Gabb)
<i>Dentalium mississippiensis</i> Con.	=	<i>D. Stramineum</i> Gabb
<i>Oliva mississippiensis</i> Conrad	=	<i>Olivella mathewsonii</i> Gabb
<i>Whitneya ficus</i> Gabb	=	<i>Whitneya ficus</i> Gabb

<i>Solarium alveatum</i> Conrad	cf.	<i>Architectonica cognata</i> Gabb
<i>Solarium amoenium</i> Conrad	=	<i>Architectonica hornii</i> Gabb
<i>Trigonoarca decisa</i> Conrad	=	<i>Arca hornii</i> Gabb
<i>Actaeon idoneus</i> Conrad	cf.	<i>A. moodyi</i> , n. sp.

Dumble⁹⁰ found an interesting Eocene locality at Topila, Mexico, Gulf Coast. At a depth of 1800 feet several shells were brought up in the oil-drilling operations. Among them were the following Tejon species: *Orbitoides*, sp., *Neverita* cf. *secta* Gabb, *Dentalium stramineum* Gabb, *Conus remondii* Gabb, *Conus californiana* (Conrad), *Turris monolifera* (Cooper), *Drillia*, cf. *ullreyana* Cooper, and *Turritella* cf. *kewi*, n. sp.

Unfortunately most of these similar or identical species are forms with very great stratigraphic range in both the Tejon and the Gulf Eocene. *Natica*, *Modiolus*, *Cadulus*, *Calyptrea*, *Olivella*, *Olivula* are particularly poor genera for correlation purposes, as specific and individual differences are not sharply marked and individual variation is great.

The occurrence of *Whitneya ficus* Gabb in lower Claiborne strata of Texas, *Solarium alveatum* Conrad and *Solarium amoenium* Conrad and a subspecies of *Venericardia planicosta* which is the equivalent of *V. planicosta hornii* (Gabb) in the Claiborne of Alabama suggests that the Rimella simplex zone, the fauna of the type Tejon, is the equivalent of the Claiborne or lower Claiborne.

STAGES OF EVOLUTION OF THE SPECIES VENERICARDIA PLANICOSTA LAMARCK

The mutations of *Venericardia planicosta* Lamarck are very suggestive. The important changes in this species, both on the Pacific and Gulf Coasts, is a progressive alteration in the strength of radial ribs and their interspaces and a similar acceleration of development.

V. planicosta venturaensis (Waring) is a higher form than *V. planicosta smithi* (Aldrich) of the Midway stage but the interspaces and ribs have the same relative width and development.

V. planicosta hornii Gabb which occurs in the Turbinolia, Rimella simplex and Balanophyllia zones of the Tejon group corresponds in the lessening width of interspace with *V. planicosta*, form *a* Harris⁹¹ of the lower Lignitic. *V. planicosta merriami* Dickerson of the Siphonalia sutterensis zone corresponds to *V.*

⁹⁰ Dumble, E. T., Science, new series, vol. 35, pp. 906-908, 1912.

⁹¹ Harris, G. D., The Lignitic Stage, Bull. Amer. Pal., vol. 2, No. 9, pp. 246-247, 1897.

planicosta, form γ Harris of the upper Lignitic or lower Claiborne stage both as regards growth stages and the mature forms.

GENERIC COMPARISON OF MIDWAY AND TEJON FAUNAS

Harris lists the following genera from the Midway stage of the Gulf Eocene:⁹²

MIDWAY GENERA	Mar.	Tej.	MIDWAY GENERA	Mar.	Tej.
Ostrea	x	x	Caricella	---	x
Plicatula	x	---	Scaphella	---	---
Pecten	x	x	Voluta	---	x
Avicula	x	x	Volutilithes	---	x
Perna	x	---	Lyria	---	x
Modiolus	x	x	Mitra	---	x
Lithodomus	---	---	Fusus	x	x
Arca	x	x	Strepsidura	x	x
Cucullaea	x	x	Exilia	---	x
Glycimeris	x	x	Pyropsis	---	---
Nucula	---	x	Leucozonia	---	---
Acila	x	x	Mazzalina	---	---
Leda	x	x	Levifusus	---	---
Venericardia	x	x	Fulgur-Perissolax	x	x
Astarte	x	x	Pseudoliva	---	x
Crassatellites	x	x	Trophon	x	x
Protocardia	x	x	Murex	---	x
Chama	---	---	Triton	x	x
Isocardia	---	x	Pyrula (=Ficopsis)	x	x
Meretrix	x	x	Calyptraphorus	---	---
Tellina	x	x	Aporrhais	x	---
Corbula	x	x	Cerithium	x?	x
Lucina	x	x	Turritella	x	x
Gastrochaena	---	---	Mesalia	---	---
Martesia	---	x	Solarium	x	x
Verticordia	---	---	Rissoina	---	---
Pholadomya	x	---	Keilostoma	---	---
Dentalium	x	x	Calyptraea	x	x
Cadulus	---	x	Xenophora	x	x
Tornatellaea	---	---	Natica	x	x
Atys	---	---	Amauropsis	x	x
Cylichna	x	x	Scala	---	x
Pleurotomella	---	---	Solariella	---	x
Surcula	x	x	Pleurotomaria (?)	---	---
Pleurotoma	x	x	Fissurella	---	x
Olivella	x	x	Enclimatoceras	x	---

Of these genera listed, *Enclimatoceras* is the one which disappeared at the end of Midway and also at the end of Martinez time.

⁹² Harris, G. D., Bulletin of American Palaeontology, vol. I, pp. 118-270, 1895-6.

Isocardia, *Martesia*, *Cadulus*, *Caricella*, *Voluta*, *Volutilithes*, *Lyria*, *Mitra*, *Exilia*, *Pseudoliva* (?), and *Scala* (*Epitonium*) are Midway genera which are represented in the Tejon but not present in the Martinez. Most of these important genera are represented in the Recent fauna of the tropics and hence the stage of evolution of the Midway fauna is apparently nearer to the Recent than the Martinez and, on the whole, is more closely related to the Tejon.

PROPOSED CORRELATION

Identical species, similar stages of generic evolution and the mutations of *Venericardia planicosta*, all show a much stronger relationship of the Tejon group to the three lower formations of the Gulf Province, the Midway, Wilcox, and Claiborne, than was suspected. Tejon time was long and was probably equivalent to Midway (in part, at least), Wilcox, and Claiborne eons. The Jackson may be represented by the upper portion of the rhyolitic tuffs, the clay rock of Turner.

This study confirms and modifies somewhat the writer's conclusion "that the Martinez is not only equivalent to a portion of the Midway, but represents a still earlier stage of the Eocene as well". The generic relations between the Tejon and Midway are so close that it seems probable that they are correlative at least in part. Possibly the Martinez is the marine equivalent of the Puerco and Torrejon of New Mexico, that is, Paleocene.

Pacific Province		Gulf Province	
Tejon	{	Siphonalia sutterensis zone	}.....Claiborne
		Balanophyllia variabilis zone	
		Rimella simplex zone.....	{ Lower Claiborne
		Turbinolia zone.....		Wilcox
			Midway
Martinez	{	Solen stantoni zone	}.....Puerco and Torrejon(?)
		Trochocyathus zitteli zone	
		Meretrix dalli zone	

GENERAL CONCLUSIONS

(1) The Tejon group is both a stratigraphic and faunal unit which is very distinct from the groups above and below.

(2) The Tejon group is unconformable upon the Martinez Eocene and Chico-Cretaceous in the vicinity of Mount Diablo. Unconformities are inferred in other areas as well.

(3) The Oligocene in the vicinity of Walnut Creek rests with apparent unconformity upon the Tejon.

(4) The Ione formation of the Sierra Nevada is the uppermost phase of the Tejon group.

(5) The deep gravels, bench gravels, the lower rhyolitic tuffs and interrhyolitic stream gravels of the Sierra Nevada are the land and stream-laid equivalents of the marine Ione Eocene, the uppermost member of the Tejon group.

(6) Four faunal zones are recognized in the Tejon group, a lowermost, the *Turbinolia* zone, then the *Rimella simplex* zone, *Balonophyllia* zone and the *Siphonalia sutterensis* zone.

(7) The fauna of the Tejon group contains about 300 species.

(8) Only 25 species range downward into the underlying Martinez Eocene and but 3 or 4 into the overlying Oligocene.

(9) The Tejon group is apparently the correlative of the Midway (in part, at least), Wilcox (Lignitic) and Claiborne, Eocene formations of the Gulf Coast Province.

DESCRIPTIONS OF NEW SPECIES

PELECYPODA

ACILA GABBIANA, n. sp.

Plate 36, figure 1

Shell small, oval with straight anterior dorsal margin which slopes steeply to a sharp angle, the junction of broadly rounded ventral margin; posterior dorsal margin gently convex; posterior end, narrowly rounded; decoration consisting of delicate divaricate sculpture crossed by incremental lines; lunule fairly definite; escutcheon long and narrow.

This species differs from *Nucula truncata*, with which it has frequently been confused, in the following respects: it is smaller, its divaricate sculpture is more delicate, its escutcheon is more definite and concentric sculpture is more regular.

Named in honor of William Gabb, pioneer palaontologist of the Pacific Coast.

Dimensions.—Height, 6 mm.; length, 9 mm.

Occurrence.—The type was found at University of California Locality 1817, lower Tejon beds, north of Coalinga. It has been reported from many other Tejon localities, from the lowermost zone of the Tejon to the uppermost. It may also occur in the Martinez group as the form listed as *Nucula* cf. *truncata* Gabb may be this species.

ARCA CLARKI, n. sp.

Plate 37, figure 12

Shell small, subquadrate, with height almost equal to length; beak inconspicuous, rounded, central; anterior margin nearly straight, extending from a bluntly pointed end to a broadly rounded ventral margin; posterior end broadly arcuate; dorsal margin straight; decoration consisting of acute ribs with interspaces about twice their width.

The more quadrate shape of this species distinguishes it from *A. hornii* Gabb.

Named for Dr. B. L. Clark.

Dimensions.—Length, 4 mm.; height, 3.5 mm.; convexity, 1.5 mm.

Occurrence.—University of California Locality 733.

CRASSATELLITES LILLISI, n. sp.

Plate 36, figure 10

Shell solid, small, trigonal, with prominent, central beaks; the anterior dorsal margin concave, sloping gently to a rounded anterior end; the posterior dorsal margin straight and sloping to a narrowly pointed posterior; ventral margin, broadly rounded; lunule large, but obscure in type specimen; fine concentric, incremental lines decorating the shell.

Only the type specimen is known. It is easily distinguished from *C. grandis* Gabb by its greater length and by the gentler slopes of its dorsal margins.

Named in honor of Miss Helen Lillis, who donated much material obtained from the type locality of this species.

Dimensions.—Height, 19 mm.; length, 26 mm.

Occurrence.—University of California Locality 1817, Fresno County California, near base of the Tejon group.

CARDIUM MARYSVILLENSIS Dickerson

Cardium dalli Dickerson, Fauna of the Eocene at Marysville Buttes, California, Univ. Calif. Publ. Bull. Dept. Geol., vol. 7, p. 269, 1913.

A new name is necessary for this species, as Heilprin had previously named a *Cardium* in honor of W. H. Dall. Renamed for its occurrence at Marysville Buttes, California.

GLYCIMERIS PERRINI, n. sp.

Plate 36, figures 6a, 6b, 6c

Shell medium in size, nearly equilateral, cordate; beak small, prominent, slightly incurved, area very small; base broadly rounded; anterior end straight and slightly shorter than the posterior end. The base is denticulated on interior. Shell is decorated by numerous fine rounded radiating ribs which vary greatly in strength over various portions of the shell. Some of the ribs are dichotomous. Interspaces are very narrow. Concentric lines of growth cross these ribs and on weathered specimens are very prominent.

This species resembles *Glycimeris cor* (Gabb) in outline but the ribs are more numerous and the interspaces are not flat and wide as in *G. cor*. Its more trigonal form is sufficient to distinguish it from *G. sagittatus* (Gabb).

Named in honor of Professor James Perrin Smith of Stanford University.

Dimensions.—Height, 12 mm.; length, 12 mm.

Occurrence.—University of California Locality 672.

GLYCIMERIS FRESNOENSIS, n. sp.

Plate 36, figure 7

Shell small, cordate, with beak decidedly twisted; anterior and posterior dorsal margins nearly straight with steep slope to arcuate ventral margin; decoration consisting of sharp dichotomous ribs.

This species is also found at the type locality of the Tejon.

Dimensions.—Length, 7 mm.; height, 7 mm.

Occurrence.—University of California locality 1817.

GLYCIMERIS HANNIBALI, n. sp.

Plate 36, figures 8a, 8b

Shell of moderate size, inflated, with broadly rounded ventral margin and prominent beak. The anterior and posterior dorsal margins are practically straight and parallel to the axis of the shell. The anterior end is nearly straight except for a very slight central concavity at the end of a broad umbonal groove. The posterior end is broadly rounded with greatest arcuity near the dorsal margin. The decoration consists of about thirty flat radial ridges equal in width to their interspaces. The interspaces are decorated by arrow-like marks as in *G. sagittata* Gabb. Area long, narrow; interior of ventral margin dentate.

This species is not orbicular like *G. sagittatus* Gabb but is more quadrate than this form. It resembles *G. veatchi* var. *major* Stanton but its height is less and it is more quadrate, its area is smaller and narrower and the interspaces between ribs are wider. This species grew considerably larger than the type, which is of medium size.

Named for Harold Hannibal, whose collections of Tertiary fossils have greatly aided the study of Tertiary palaeontology.

Dimensions.—Height, 20 mm.; length, 22 mm.

Occurrence.—University of California Locality 672 at the top of the white sandstone member of the Tejon group north of Coalinga.

LEDA FRESNOENSIS, n. sp.

Plate 36, figures 2a, 2b

Shell long, rather robust for this genus; beak prominent and situated two-fifths of the length from the anterior end. Anterior

dorsal margin straight with moderate slope; the posterior dorsal margin slightly concave with a gentle slope to a narrowly rounded rostrum; posterior end, narrowly rounded; ventral margin, broadly convex. Very fine growth lines decorate the shell.

This species is larger, its rostrum is less pointed and its ribbing much finer than *L. gabbi* Conrad.

Dimensions.—Height of broken specimen, the type, 13 mm.; length, 22 mm.

Occurrence.—University of California Locality 1817.

LUCINA PACKI, n. sp.

Plate 36, figure 12

Shell small, subcircular in outline; posterior dorsal margin straight with moderate slope to a subtruncate posterior; beak sub-central, rounded, prominent; decoration consisting of very fine sharp concentric lines of growth.

Named for Robert Pack, Palaeontologist, U. S. Geological Survey.

Dimensions.—Length, 8.5 mm.; height, 8 mm.

Occurrence.—Type is from University of California Locality 672.

LUCINA DIEGOENSIS, a. sp.

Plate 37, figures 1a, 1b

Shell medium in size, orbicular, thick, with central prominent beaks. Lunule wide, short, and very prominent; escutcheon long, narrow; anterior dorsal margin markedly concave under the beaks; the slightly convex posterior dorsal margin slopes with moderate angle to a truncated posterior end; ventral margin nearly semi-circular; right and left valves equal. The surface is marked by strong, sharp concentric incremental lines and by a feebly developed umbonal groove which extends to the middle of the posterior extremity.

This species is thicker than *L. annulatus* or *L. acutilineatus* and it differs from both in the greater slope of its posterior dorsal margin.

Dimensions.—Height, 29 mm.; length, 32 mm.; thickness of two valves, 16 mm.

Occurrence.—University of California Locality 2226, Tejon of Rose Cañon, San Diego County, California.

MARCIA(?) CONRADI, n. sp.

Plate 38, figure 3

Shell small, ovate, thick, with thin shell substance; beak located one-third the distance from anterior end, rounded and prominent;

ventral margin broadly arcuate; posterior end subtruncate, resembling that of *Marcia quadrata* (Gabb); anterior end moderately convex; posterior dorsal margin slightly convex with gentle slope; anterior dorsal margin slightly convex with moderate slope to the rounded anterior end.

This species somewhat resembles *Marcia quadrata* (Gabb) but is less elongate, its anterior end is more rounded and its posterior dorsal slope is greater.

Named in honor of T. A. Conrad, the eminent palaeontologist who first recognized Eocene strata on the Pacific Coast.

Dimensions.—Length, 18 mm.; height, 15 mm.; thickness, 5 mm.

Occurrence.—The type was found at University of California Locality 1817, lower Tejon, northwest of Coalinga, California.

PHACOIDES (MYRTEA) TAFFANA, n. sp.

Plate 36, figure 11

Shell small, compact, trigonal; beak small, prominent, opisthodontic; concentric growth lines prominent, lamelliform. A marked posterior fold extends from the beak to the posterior end; posterior dorsal margin slightly convex; anterior dorsal margin slightly concave; base rounded. Area small and not distinctly set off. Pallial line simple, entire; two cardinal teeth in right valve, the posterior one being bifid; two cardinal teeth in left valve; a posterior lateral and an anterior lateral tooth are found in the right valve with corresponding sockets in the left valve.

Named in honor of Mr. J. A. Taff, Geologist, Southern Pacific Company.

This species is easily distinguished from *Diplodonta polita* (Gabb) by its lamelliform concentric ribs.

Dimensions.—Height of a right valve, 5 mm.; length, 5.5 mm.

Occurrence.—University of California Locality 672.

SPISULA MERRIAMI Packard

Plate 39, figures 2a, 2b, 2c

Shell small, trigonal, equivalve, nearly equilateral, slightly ventricose, ornamented by numerous fine concentric ridges which are more pronounced and less numerous on the anterior and posterior dorsal areas than upon the other portions of the shell; beaks moderately prominent, anterior dorsal area limited by a distinct ridge extending from the umbo to the anterior extremity; the margin of this area is

nearly straight; posterior dorsal slope slightly convex, limited by an indistinct ridge which extends from the beak to the base of the shell; anterior extremity more sharply pointed than the posterior; base very broadly rounded, hinge plate relatively broad, chondophore oblique, shallow, apically roofed by a broad flat spur; left cardinal prominent, high, arms broad, extending from the dorsal to the ventral margin of the plate; ventral sinus narrow, flat; right cardinal with a prominent anterior arm, and a well-developed, although relatively thin posterior arm; laminae long, distant from the beaks; anterior lateral formed from the margin of the plate, with top rounded, distant from the anterior arm of the cardinal; posterior lateral also with rounding top, dorsal and ventral slopes nearly equal; anterior ventral lamina formed from the upturned edge of the hinge plate, and not confluent with the anterior cardinal arm; anterior dorsals scarcely developed, considerably smaller than the corresponding posterior one. The general shape is quite uniform.

This trigonal species might be mistaken for *S. ashburneri* (Gabb). It differs from that Cretaceous species in being less ventricose; in having more pronounced concentric sculpture; and in the possession of a well-developed posterior cardinal arm.

Type described from Parson's Peak, Fresno County, California, University of California Locality No. 672.

Occurrence.—Eocene, Tejon group, Parson's Peak, south side of Mount Diablo, and Salt Creek, Fresno County, California (Dickerson).

Dimensions.—Length, 18.6 mm.; height, 14.2 mm.; convexity, 4 mm.

TIVELA PACKARDI, n. sp.

Plate 38, figures 2a, 2b

Shell small, trigonal in outline; base broadly rounded; beak small, prominent; lunule inconspicuous and not definitely set off. The slightly convex posterior dorsal margin is gentler than the anterior dorsal margin. A rounded umbonal slope extends from the beak to a point where the rounded base meets the slightly convex posterior end; anterior end sharply rounded. The shell is decorated by sharply rounded lines of growth. These growth lines are few and larger upon the posterior dorsal slope. The dentition is characteristic of the genus.

Named in honor of Dr. Earl Packard.

Dimensions.—Height, 10 mm.; length, 12 mm.

Occurrence.—University of California Locality 672.

TELLINA JOLLAENSIS, n. sp.

Plate 37, figure 3

Shell small, thin, with subcentral rounded beak; posterior dorsal margin with moderate slope to a pointed posterior; anterior dorsal margin with but a slight slope to a rounded anterior; ventral margin very broadly rounded; decoration consisting of fine lines of growth only.

Named for the occurrence of this species in the La Jolla Quadrangle, San Diego County, California.

Dimensions.—Length, 24 mm.; height, 14 mm.; thickness of two valves, 5 mm.

Occurrence.—University of California Locality 2226.

GASTROPODA

ARCHITECTONICA ULLREYANA, n. sp.

Plate 40, figures 5a, 5b

Shell small, with five whorls coiled in a nearly flat spire. The decoration on the upper surface of the whorls consists of eight to twelve beaded threads. The upper surface of the body whorl is slightly concave and is decorated by about twelve beaded spiral threads. The two threads near the suture are larger than all the rest except the one on the periphery of the body-whorl forms a well-marked keel. The base is decorated by about fifteen nodose spiral threads similar to those upon the upper surface; a specially strong one marks an angulation upon the body-whorl. Mouth, quadrangular.

The low spire of this species readily distinguishes it from *A. hornii* Gabb and *A. cognata* Gabb. Its decoration resembles that of *A. tuberculata* Weaver closely but it has a greater number of threads upon the upper surface of the body whorl. They may be the same species but only the cast of the upper surface of *A. tuberculata* exists. Their relations will remain indeterminate until better material is found at the type locality of *A. tuberculata*, University of California Locality 541.

Named in honor of Mr. Bert Ullrey of West Butte, California, who assisted Mr. Watts in collecting at this locality.

Dimensions.—Altitude, 2 mm.; maximum diameter, 5 mm.

Occurrence.—University of California Locality 1853.

ACTAEON MOODYI, n. sp.

Plate 38, figures 10a, 10b

Shell ovate; spire low, conical; whorls five and a half, the first two being smooth nuclear. The shell is decorated by strong, evenly spaced, equal spiral lines, four of which mark the third whorl, five the fourth, and about eighteen the body-whorl. Whorls convex, rounded; suture linear; mouth suboval; outer lip simple; columella marked by the faint single plait of this genus.

Named in honor of Mr. Wilbur Moody, Field Geologist, Southern Pacific Company.

This species is higher and less globose than *A. lawsoni* of the Martinez group and its spire is less acute.

Dimensions.—Length, 9 mm.; width of body-whorl, 5 mm.

Occurrence.—University of California Locality 672.

ACMAEA RUCKMANI, n. sp.

Plate 39, figure 3

Shell small, low, nearly circular in outline; apex subcentral, slightly curving forward; surface decorated by about 25 thread-like radiating ribs, with flat interspaces three times as wide as ribs. Three or four concentric growth lines cross the radial ribs.

This species differs from *A. tejonensis* Gabb in its pronounced radial decoration and in its nearly circular shape.

Named in honor of Mr. John Ruckman, who aided the writer in collecting at the above locality.

Dimensions.—Length, 8 mm.; width, 7 mm.; height, 4 mm.

Occurrence.—University of California Locality 2225, south side of Oroville South Table Mountain.

CHRYSDOMUS MARTINI Dickerson

Plate 39, figure 8

Phos(?) martini Dickerson, Fauna of the Eocene at Marysville Buttes, California, Univ. Calif. Publ. Bull. Dept. Geol., vol. 7, p. 288. 1913.

The type of the species described under the above name was defective. Better specimens of this same species were found at University of California Locality 2225, south side of Oroville South Table Mountain. They have moderately long, curved, slender canals and other characters of the genus *Chrysodomus*.

CREPIDULA INORNATA, n. sp.

Plate 38, figures 5a, 5b

Shell subovate, smooth, number of whorls about two and a half; spire twisted, suture obscure; deck about a third the length of shell; margin of deck convex on outside and concave near inner edge.

This species has been figured as a "high" form of *Galerus excentricus* Gabb but its deck is distinctive of the genus *Crepidula*. *G. excentricus* Gabb occurs with it but interior is quite different.

This species differs from *Crepidula* (*Spirocrypta*) *pileum* Gabb in that its spire is not immersed and the margin of its deck is not convex in the center.

Dimensions.—Height above base, 4 mm.; length, 8 mm.

Occurrence.—University of California Locality 672.

CERITHIOPSIS DUMBLEI, n. sp.

Plate 38, figure 12

Shell elongate conical with nine whorls; the first two nuclear whorls are smooth. The last seven are decorated by four spiral lines of equal strength and equally spaced. Suture linear, impressed, the space between two whorls being of the same width as that between two of the spiral lines. Axial ribs, twelve to fourteen in number. Occasionally these ribs are swollen to form slight varices. Base of body-whorl is decorated by fine spiral threads only.

This species differs from *C. alternata* Gabb in that it lacks the minor spiral threads. It differs from *C. orovillensis* Dickerson in its greater length, in the regular spacing of its four spiral lines and its lack of pronounced varices.

Named in honor of Professor E. T. Dumble, consulting geologist, Southern Pacific Company.

Dimensions.—Length, 9.5 mm.; width of body-whorl, 4 mm.

Occurrence.—University of California Locality 672.

CERITHIOPSIS OROVILLENSIS, n. sp.

Plate 39, figure 7

Shell medium in size for this genus, light-colored, conical. Nuclear whorls decollated. A strongly channeled suture separates the post-nuclear whorls. The fourth whorl is marked by three equidistant spiral cords with interspaces equal in width to the cords. About fourteen vertical axial ribs equal in strength to the cords also mark

this whorl. The junctions of the spiral cords form rounder tubercles and spaces between appear to be round. The fifth, sixth, seventh and eighth whorls are decorated by four spiral cords, the first of which is slightly anterior to the summit; the second equal in size to first, and separated from it by an interspace equal in width to the first cord. These two cords occupy about the upper two-fifths of the whorl, while the two lower and much stronger cords cover the rest of the whorl. Vertical axial ribs slightly weaker than the spiral cords also mark these whorls. The nodes made by the crossing of the two sets of lines are elongated from left to right. This is most marked in the two posterior ribs. In addition to these decorations swollen varices occur upon the whorls at irregular intervals. These varices are very strongly marked by the spiral cords, the axial ribs being very weak. Of the axial ribs fifteen occur upon the fifth, sixteen upon the sixth, twenty upon the seventh and eighth. The ninth, or body-whorl, is similarly decorated. Its base is marked by two strong spiral keels, the first of which is nodose, and by six or seven spiral lines. Aperture roughly oval; columella twisted and covered by a thin callus.

This species is much smaller than either *C. excelsa* Dall or *C. alternata* Gabb. Its well-marked varices and the lesser number of spiral cords distinguish it at once from *C. excelsa*. It is broadly conic while *C. alternata* is elongate conic. *C. orovillensis* n. sp. has two sets of spiral cords, an upper and weaker and a lower and stronger, while the weaker and stronger cords of *C. alternata*, as the name suggests, alternate.

Dimensions.—Length, 6 mm.; diameter, 2 mm.

Occurrence.—University of California Locality 2225, south side of Oroville South Table Mountain.

DRILLIA OROVILLENSIS, n. sp.

Plate 41, figure 4

Shell slender, fusiform, with spire acutely pointed; whorls eight, of which two nuclear are smooth; last whorl three-fifths of the length of the shell. The transverse sculpture consists of twelve sharply elevated flexuous ribs with interspaces twice their width and fine threads parallel to ribs in the interspaces. These ribs are largest at the shoulder, which is located at the middle of a spire-whorl. Five spiral lines cross the ribs and one larger than the rest is found at the angle. The flexuous transverse ribs on the body-whorl extend from the linear

suture over three-fourths of its length. The sinus is shallow and slightly above the shoulder. Aperture elongate-oval; canal long, slender, straight.

This species differs from *D. ullreyana* Cooper in its greater length, in its more elongate and less nodose, transverse ribs which are more numerous than those of *D. ullreyana*.

Dimensions.—Length, 7.5 mm.; diameter, 2.5 mm.

Occurrence.—University of California Locality 2225, south side of Oroville South Table Mountain, Butte County, California.

DRILLIA COOPERI, n. sp.

Plate 40, figures 6a, 6b

Shell spindle-shaped with ten slightly convex whorls; the first two nuclear whorls are smooth and slightly more convex than the rest. The third and fourth whorls have a slight angulation just above a linear impressed suture. The last eight whorls are decorated by five spiral threads or bands crossed by growth lines characteristic of this genus. The band just below the suture is flat and slightly wider than the next three. The three or four threads below the suture on the last five whorls are stronger than the rest. The body-whorl and canal are together nearly twice as long as the spire. The mouth is oval and narrows gradually into a long nearly straight canal; outer lip smooth; inner lip with a very slight callus.

This species can be readily distinguished from the other west coast Eocene forms of the genus *Drillia* by its nearly smooth whorls.

Named in honor of Dr. J. G. Cooper, who first described species from this vicinity.

Dimensions.—Length of broken specimen, 20 mm.; length of spire, 9 mm.; width of body-whorl, 8 mm.

Occurrence.—University of California Localities 785, 1853; type specimen from latter locality.

EPITONIUM TEJONENSIS, n. sp.

Plate 38, figure 4

Shell elongate, only moderately slender, whorls nine, the first two being smooth; mouth round; whorls convex and decorated by spiral lines and by varices, the latter being the more pronounced. The body-whorl has about twenty-five varices which run almost to the linear suture. These varices are slightly swollen in the middle of

each whorl. About ten faint spiral threads cross the varices, forming slight nodes at their intersection. A strong spiral cord ridges the base of the body-whorl. The body-whorl is much expanded in comparison with the spire whorls. The spire whorls are decorated in a similar fashion to the body-whorl. The varices, however, are less numerous on the upper whorls.

This is the first time that this genus has been reported from the Eocene of the Pacific Slope. A cast of what appears to be this same species was found in the Eocene of the Marysville Buttes.

Dimensions.—Length, 13 mm.; width of body-whorl, 5.5 mm.

Occurrence.—University of California Locality 672.

GALEODEA SUTTERENSIS, n. sp.

Plate 40, figures 1 and 2

Shell large, solid with great body-whorl and short spire; whorls seven, tabulate; spire whorls exhibiting a well-marked nearly square shoulder which is nodose at the crossing of the fine, sinuous growth lines and the strong spiral line marking the shoulder; fine spiral lines subequal in strength decorating whorls; body-whorl at shoulder marked by about fourteen sharp, elongate spinous nodes; one or two rows of nodes decorating body-whorl in addition to shoulder nodes; mouth oval; outer lip thickened; inner lip heavily incrustated; canal long and twisted.

This species differs from *G. tuberculata* (Gabb) in its more spinous nodes and in its much longer canal.

Dimensions.—Length, 35 mm.; width of body-whorl, 27 mm.

Occurrence.—University of California Locality 1853.

FICOPSIS COOPERII Gabb

Plate 37, figure 7

Gabb's type was a much eroded specimen obtained from the Tejon of Rose Cañon, San Diego County, California. The specimen figured in this paper shows three rows of sharply pointed nodes instead of rounded ones on the body-whorl. The shoulder is markedly square in contrast to Gabb's figure, in which there is a marked slope from suture to second row of nodes on the body-whorl. As Gabb predicted, the shell is ornamented by very fine spiral lines. Mouth has three marked angulations on outer lip. This species is easily distinguished from *Ficopsis cowblitzensis* Weaver by its larger nodes and by the

irregular distribution of the nodes and by the smaller number of of nodes.

The figured specimen was obtained from the type locality in Rose Cañon, University of California Locality 2226.

FASCIOLARIA BILINEATA, n. sp.

Plate 37, figures 6a, 6b

Shell fusiform with moderately long, narrow canal; seven or eight whorls. The first three nuclear whorls, smooth. The last four or five whorls are decorated by two very strong spiral lines, the upper one of which marks a very prominent shoulder on the whorls of mature specimens. These spiral lines are crossed by eight to ten axial ribs which extend from suture to suture. The space between the wavy suture and the shoulder is covered by fine spiral threads; outer lip crenulate; inner lip with three oblique plaits.

The younger specimens do not show the shouldering on the whorls but have rounded whorls instead. The number of whorls was obtained from a study of a young specimen.

Dimensions.—Height of broken type, 15 mm.; width of body-whorl, 9 mm.

Occurrence.—The type specimen was obtained from the Tejon of Rose Cañon, San Diego County, California, University of California Locality 2226.

FUSINUS MERRIAM, n. sp.

Plate 40, figures 2a, 2b

Shell with long, acuminate spire and with long, straight, narrow canal; whorls, eleven in number; the first two rounded; the other whorls are angulated at a point about two-thirds of a whorl-length below the suture. The last nine whorls have the angle marked by ten flat pointed nodes which are decidedly upturned on the body-whorl. The space above the angle of a whorl is decorated by seven to ten spiral lines and by five growth lines of about the same strength. Below the angle are found three or four spiral lines which alternate in size. The decoration on the body-whorl is similar to that of the spire-whorls. The spiral lines below the angle on the body-whorl are eight in number.

Named in honor of Professor J. C. Merriam, whose kindly criticism has been of great service in the preparation of this paper.

Dimensions.—Length of nearly perfect specimen, 24 mm.; width of body-whorl, 7 mm.; length of spire, 10 mm.

Occurrence.—University of California Locality 1853.

MONODONTA WATTSI, n. sp.

Plate 40, figures 3a, 3b

Turbinata, with five convex whorls; the first two are smooth; the remaining whorls are decorated by slightly nodose spiral lines. A fairly well developed collar with spiral threads upon it is found on the body-whorl just below the linear suture. The threads upon this collar and upon the base are finer than those of the central portion of the whorls. Outer lip simple; inner lip thinly callused; a single tooth characteristic of the genus is found upon the columella.

This species is also found in the Tejon at California Academy of Sciences Locality 240, near Vader, Washington.

Named in honor of Mr. W. L. Watts who first collected at this locality.

Dimensions.—Length, 6 mm.; width of body whorl, 7 mm.

Occurrence.—University of California Locality 1853.

METULA HARRISI, n. sp.

Plate 42, figure 1

Shell elongate fusiform, with spire about as long as the body-whorl. Whorls are seven or eight in number, the two upper ones being lost. The last three whorls are cancellated by one or two long, rounded varices. The body-whorl and the two preceding whorls are decorated by axial ribs and spiral lines of equal strength, giving the shell a reticulated appearance. Outer lip thickened; inner lip covered by a thin, long callus; canal short, slightly twisted.

This form is very similar to *M. sylvaerupis* Harris of the Lignitic Stage of the Gulf Coast Eocene. It appears to differ from *M. sylvaerupis* in its lack of "one or two comparatively large spiral lines on the humeral slope."

Named in honor of Professor G. D. Harris of Cornell University, whose standard works on the Eocene of the Gulf Coast have been of great service to the writer.

Dimensions.—Length of broken specimen, 17 mm.; width of body-whorl, 6 mm.

Occurrence.—University of California Locality 1817.

MITRAMORPHA PARSONSI, n. sp.

Plate 38, figure 11

Shell fusiform, with spire almost as long as body-whorl; whorls eight, the first three being smooth; the other whorls strongly cancellated by rounded elongated varices. Eight varices are found on fourth whorl, seven on the fifth, six on the sixth and seventh, and four on the body-whorl. The spire-whorls except the first three are distinctly shouldered about a third of the distance below the sinuous, linear suture. The space between the apex and shoulder of these whorls is covered by two or three small spiral threads, while the space below the shoulder is decorated by two to four spiral lines with intercalary threads. These spiral lines number about twenty on the body-whorl. Mouth elongate-oval; outer lip thickened; inner lip marked by six plaits, the uppermost being the strongest.

Named in honor of Mr. Benjamin Parsons, some time field geologist, Southern Pacific Company.

Dimensions.—Length, 12 mm.; width of body-whorl, 4.5 mm.

Occurrence.—University of California Locality 672.

MUREX (OCINEBRA) NASHI, n. sp.

Plate 41, figures 7a, 7b

Shell short, with small spire and large body-whorl; nucleus small, smooth, of three whorls; remaining four whorls decorated by very prominent sculpture, consisting of twelve to fourteen equally spaced, thick lamelliform varices, which are thick, sharp and spinose at the intersection of the spiral ribs, especially prominent at the shoulder; spiral sculpture of spire consists of four rounded cords between suture and shoulder; shoulder is marked by a larger spiral cord, below which are two or three more spiral cords similar to the ones above the shoulder; interspaces linear. All the cords tend to form spines upon crossing the varices. The body-whorl is similarly decorated except that there are four major spiral cords below the shoulder, the upper two being most prominent. Two minor cords are found between the major. Aperture ovate; canal short, wide and recurved; outer lip with five or six coarse lirae within; inner lip covered by a thin columellar fold.

Named in honor of Mrs. Louise Nash, whose excellent drawings have aided work in palaeontology.

Dimensions.—Length, 12 mm.; diameter, 8 mm.

Occurrence.—University of California Locality 2225, Oroville South Table Mountain, Butte County, California.

NATICA GESTERI, n. sp.

Plate 38, figure 6

Shell small, high, with five whorls. The spire, one-fourth the shell-length, has slightly convex, smooth whorls. The body-whorl which is unusually elongate for this genus is gently convex. Aperture semilunar; outer lip simple; inner lip incrustated; umbilicus small, narrow, resembling that of *Lunatia hornii* Gabb.

The greater length of this species distinguishes it from other naticoid forms of the Tejon.

Named for Mr. Clarke Gester who discovered this species.

Dimensions.—Length, 15 mm.; width of body-whorl, 9 mm.

Occurrence.—University of California Locality 1817.

NYCTILOCHUS THUNANI, n. sp.

Plate 41, figures 8a, 8b

Shell fusiform, with moderately high spire; whorls seven, the first two whorls being smooth; third whorl decorated with ten swollen nodes which extend from suture to suture; fourth, fifth, sixth and seventh whorls are decorated by similar elongate nodes which become decidedly sinuous upon the body-whorl; suture sinuous, distinct; body-whorl has a wide mouth which is narrowed in advance; canal recurved, twisted; outer lip thickened and denticulated on interior; inner lip covered by a slight callus. Numerous well-marked revolving lines which alternate regularly in size, cover all the last five whorls; these lines are crossed by finer axial lines which vary but slightly.

This species resembled *Nyctilochus whitneyi* (Gabb), but its spire is shorter, mouth wider, body-whorl stouter and the spiral lines alternate regularly in size. There are occasionally as many as four minor spiral lines between major spiral lines on *N. whitneyi* and the major ones are more strongly set off than in *N. thunani*.

Named in honor of Mrs. Fred Thunan of Oroville, who presented the type to the University of California.

Dimensions.—Height, 19 mm.; width of body-whorl, 12 mm.

Occurrence.—University of California Locality 2225, about one mile north and three degrees west of Butte County Hospital, Tejon of Oroville South Table Mountain.

NYCTILOCHUS DIEGOENSIS (Gabb)

Plate 41, figures 6a, 6b

Tritonium diegoensis Gabb, Geological Survey of California, Palaeontology, vol. 1, p. 95, 1864.

This species occurs in the Tejon of Oroville South Table Mountain. Several specimens exhibit the aperture and the canal far better than Gabb's type. The canal is very short and narrow and the outer lip is thickened and denticulated. In the type the canal and aperture are obscured by the rock matrix.

PERISSOLAX GABBI, n. sp.

Plate 37, figure 14

Shell thick, spire moderately high (?), body-whorl prodoundly angulated at a point one-third of its length from the posterior; suture distinct; portion of whorl above shoulder slightly convex and nearly at right angles to the axis; body-whorl decorated by very prominent axial ribs which extend from the suture over the entire whorl. These ribs have flat-pointed nodes at the shoulder and are nearly obsolete at either end. Revolving lines of moderate size with minute interlacing riblets cover the entire shell. These lines are crossed by fine growth lines which give portions of the surface a reticulated appearance. Four or five of these revolving lines are found above the shoulder of the body-whorl. Mouth quadrate; outer lip simple and divided in thirds by two angulations; inner lip slightly incrustated; canal long and nearly straight.

It appears to be a descendant of *Parissolax brevirostris* Gabb of the Chico (Cretaceous), to which it bears a striking resemblance. *P. brevirostris* has three distinct angulations on outer lip and a rounded body-whorl, while *P. gabbi* has only two angulations on outer lip and a decidedly angular body-whorl. *P. gabbi* is also less robust. The genus *Perissolax* resembles *Tudicla* of the eastern Eocene in general appearance. They both appear to belong to the Fulguridae rather than to the Fusidae as Gabb suggested.

Named in honor of W. M. Gabb, who laid the foundation of palaeontology on the Pacific Coast.

Dimensions.—Length of broken specimen, 25 mm.; width of body-whorl, 14 mm.

Occurrence.—The specimen figured was found at University of California Locality 532, Solen Stanton Zone, where it was associated with *Solen stantoni* Weaver and *Thracia karquinesensis* Weaver.

ODOSTOMIA PACKI, n. sp.

Plate 37, figure 11

Shell small, elongate, slender, with at least twelve whorls; spire high with acute apex; whorls flat-sided, smooth or ornamented by very fine spiral threads, suture distinct, linear, channeled; aperture round; outer lip marked by an internal spiral rib; inner lip by two plaits, which are characteristic of this genus.

Named in honor of Robert W. Pack, Palaeontologist, U. S. Geological Survey.

Dimensions.—Length of broken type, 10 mm.; width of body-whorl, 3.5 mm.

Occurrence.—The type is from University of California Locality 2226, Rose Cañon, San Diego County, California. This species also occurs at University of California Locality 1817, lower Tejon beds north of Coalinga, California and at California Academy of Sciences Locality 183, Vader, Lewis County, Washington, in the west bank of the Cowlitz River about one and three-fourths miles southeast of Vader or about one-half mile south of Locality 182.

STREPSIDURA HOWARDI, n. sp.

Plate 37, figure 13

Shell robust, medium in size, with twelve prominent, rounded nodes; number of whorls unknown; suture wavy; body-whorl swollen; strong spiral lines about twenty in number decorating the body-whorl; mouth semi-oval; outer lip thin; inner lip but slightly incrustated.

Dimensions.—Length of broken type, 27 mm.; width of body-whorl, 23 mm.

Occurrence.—University of California Locality 476.

SIPHONALIA SUTTERENSIS Dickerson

Plate 41, figures 5a, 5b, 5c, 5d, 5e

Siphonalia sutterensis Dickerson, "Fauna of Eocene at Marysville Buttes, California," Univ. Calif. Publ. Bull. Dept. Geol., vol. 7, p. 283, 1913.

A large series of specimens of this species were collected at University of California Locality 2225. The younger specimens are slenderer than the mature forms, the canal is less bent, the spiral ribbing on the body whorl is more conspicuous, and nodes of the body whorl are less marked. A young specimen resembles a form belonging to the genus *Nyctilochus*.

SURCULA CLARKI Dickerson

Plate 41, figures 1a, 1b

Surcula clarki Dickerson, "Fauna of the Eocene at Marysville Buttes, California," Univ. Calif. Publ. Bull. Dept. Geol., vol. 7, p. 278, 1913.

A series of specimens found in the Tejon of Oroville South Table Mountain shows a variation in form as the above-mentioned species grows in size. The shouldering of the large specimens is far more prominent than in the type and the surface between the shoulder and suture of the larger whorls is distinctly concave.

SURCULA GESTERI, n. sp.

Plate 42, figure 4

Shell spindle-shaped with eight whorls; the three nuclear whorls the smooth; the other whorls of the spire are decorated by two rows of rounded nodes made by the crossing of about sixteen axial ribs and two strong spiral lines. The upper row of nodes is slightly larger and they mark the shoulder of the whorl. The space between the shoulder and the appressed suture is concave and marked only by spiral lines. The body-whorl has a similar set of axial ribs crossed by six subequal spiral lines in its upper half and by about six spiral threads which alternate in size on its lower half. Sinuous growth lines characteristic of this genus mark the space above the shoulder. The sinus is also found on the thin outer lip of some specimens. Mouth elongate-oval; inner lip slightly incrustated.

Its double row of rounded nodes will serve to distinguish it at once from other members of this genus which have thus far been described from the Tejon group. The older specimens are somewhat more elongate than younger ones and body whorl is not so wide.

Named in honor of Mr. Clarke Gester.

Dimensions.—Length, 9 mm.; width of body-whorl, 3 mm.

Occurrence.—This species was found at University of California Locality 672.

TURRIS STOCKI, n. sp.

Plate 42, figure 5

Shell spindle-shaped with nine or ten whorls; the first two or three whorls of the type specimen are missing. The spire-whorls are decorated by a nodose spiral line in the center of each whorl. Separated from this central line by a wide space are two closely

set spiral lines, both above and below, adjacent to the linear impressed suture. The decoration of the body-whorl consists of a nodose spiral line at the shoulder; twelve to fifteen spiral lines are found below the shoulder, minor threads occurring between these lines.

This species is distinguished from *T. monolifera* (Cooper) by its greater number of nodes and by greater spire length.

Named in honor of Mr. Chester Stock, graduate student, University of California.

Dimensions.—Length, 14 mm.; width of body-whorl, 4.5 mm.

Occurrence.—University of California Locality 672.

TURRITELLA BUWALDANA, n. sp.

Plate 42, figures 7a, 7b

Shell slender, elongate; whorls fourteen or fifteen; each flat-sided whorl carinated near base, diminishing in diameter toward the apex. Sculpture consists of two small spiral threads just above a linear suture, then four strong spiral lines with an intercalary thread and two threads close together on apex. The differences in these lines are more emphasized in the younger specimens and in the lower whorls of older specimens. The two small threads just above and the two just below the suture of the last whorls of a large specimen are absent, the intercalary threads are much stronger than in the upper whorls and the four principal ribs are practically equal in strength. Spiral lines alternating in size decorate the base of the body-whorl. Sinuous lines of growth cross the spiral lines.

This species has a flat-sided whorl while *T. uvasana* Conrad has a convex whorl. The major spiral ribs of *T. uvasana* Conrad are equally accentuated and evenly spaced while on *T. buwaldana*, n. sp. they vary in strength.

The younger whorls of this species resemble those of *T. merriami* Dickerson closely but the development of the later whorls in the two cases is opposite. The principal carina on *T. merriami* becomes more and more pronounced while the reverse is true with the species described above. This species has also been found at the type locality of the Tejon group on the Cañada de las Uvas. It is very close to a *Turritella* described by Arnold as *Turritella martinezensis* (?) var. *lom pocensis*. This form is really a species and not a variety. The principal differences appear to be as follows: *T. lom pocensis* has a slightly concave whorl while *T. buwaldana* is

flat; the lower carina becomes more prominent on *T. lompocensis* on the later whorls whereas the reverse is true on the other; the two sets of spiral threads on either side of the suture appear to be absent on *T. lompocensis*.

Named in honor of Dr. John P. Buwalda.

Dimensions:—Length of medium-sized specimen, .20 mm.; diameter, 6 mm.

Occurrence:—University of California Locality 672 in white sandstone of the Tejon group just beneath the overlying diatomaceous shale.

TURRITELLA KEWI, n. sp.

Plate 42, figure 8

Shell long, slender; whorls probably about thirteen or fourteen in number; each flat-sided whorl is decorated by five spiral lines with a single fine thread in the interspace. The spiral lines consist of two sets, an upper one near the suture of three closely set lines and a lower of two lines which are relatively widely separated. The suture linear, impressed, slightly below the surface of the flat-sided whorls. Mouth, quadrate.

This species is distinguished from *T. buwaldana*, n. sp. by a different suture, by a great apical angle and by its decoration. It occurs with *T. uvasana* and with *T. buwaldana* at University of California Locality 672.

Named in honor of Mr. William Kew.

Occurrence:—University of California Locality 672, Tejon of Fresno County, California.

Dimensions:—Length of broken type, 22 mm.; width of body-whorl, 8 mm.

TURRITELLA ANDERSONI, n. sp.

Plate 42, figures 9a, 9b

Shell very elongate with about sixteen whorls which increase but slightly in size. The sides of the whorls are flat and in the type are decorated by minute obscure spiral threads crossed by small sinuous growth lines. Suture impressed, linear.

This species differs from *T. uvasana* Conrad in shape of whorls, in lack of strongly marked ribbing and in having a smaller apical angle.

It differs from *T. pachecoensis* Stanton with which it has been

confused in the following respects: its apical angle is smaller; its whorls are flat and not angulated distinctly near the suture and it is smaller.

It may be identical with *T. conica* Weaver but the type of this last species is such a poor one that this point can not be decided.

A spirally ribbed form which is apparently an individual variation is found associated with the typical form described above. This form is also figured. (See figure 9b.)

Named in honor of Mr. F. M. Anderson, curator of the Department of Palaeontology, California Academy of Sciences, who first studied the fauna from the type locality of this species.

Dimensions:—Length of broken type, 28 mm.; width of last whorl on type, 8 mm.

Occurrence:—The type specimen was obtained from University of California Locality 1817, lower Tejon of Fresno County, where it is very abundant. Collectors, Clarke Gester and R. E. Dickerson. It is also found at University of California Locality 1428, which is about fifteen hundred feet above the base of the Tejon south of Mount Diablo.

TURRITELLA LAWSONI, n. sp.

Plate 42, figure 10

Shell elongate conic; number of whorls unknown; suture linear, impressed; whorl slightly concave with center of concavity below middle; lower fourth of whorl flat with surface parallel to axis; base of whorl, nearly flat, overhanging succeeding whorl, making an acute angle with axis of shell; decoration consisting of numerous fine threads of variable strength.

Dimensions:—Height, 36 mm.

Occurrence:—Tejon group. Section 24, Domengine Ranch. Coll. F. M. Anderson, University of California Locality 2295.

XENOPHORA STOCKI, n. sp.

Plate 37, figures 4a, 4b

Shell, low trochiform with six whorls; shell substance thin. Whorls are medially shouldered, with steep slope from a wavy, linear suture to the shoulder. The space between the shoulder and the next whorl is parallel to the axis of the shell. This space is further decorated by about seven roughened nodes whose apices are at the shoulder. The shell surface is pitted in several places. These round

pits were once occupied by pebbles which the animal had agglutinated to its shell. Only the type specimen and a fragment are known.

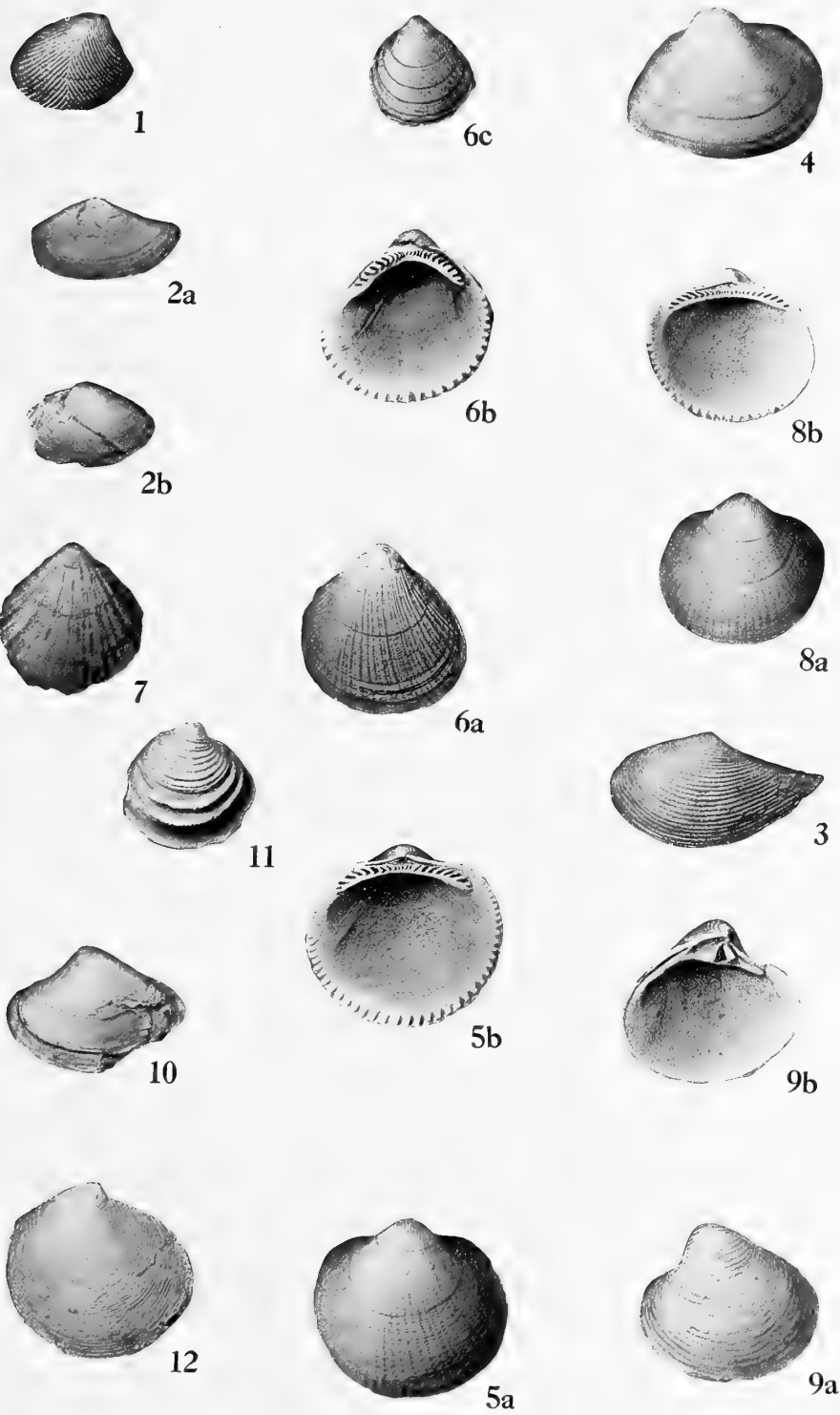
Named for Mr. Chester Stock who has assisted the writer on numerous occasions and who collected the type from the Tejon of Rose Cañon.

Dimensions:—Height of broken type, 18 mm.; width of body whorl, 30 mm.

Occurrence:—University of California Locality 2226, Tejon group, Rose Cañon, San Diego County, California.

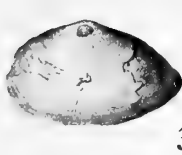
EXPLANATION OF PLATE 36

- Fig. 1. *Acila gabbiana*, n. sp., $\times 3$.
 Fig. 2a. *Leda fresnoensis*, n. sp. $\times 1$. Left valve of type.
 Fig. 2b. *Leda fresnoensis*, n. sp., $\times 1$. View showing anterior end of right valve of a cotype.
 Fig. 3. *Leda gabbi* Conrad, $\times 2$. U. C. Locality 672.
 Fig. 4. *Arca hornii* Gabb, $\times 2$. U. C. Locality 672.
 Fig. 5a. *Glycimeris sagittatus* Gabb, $\times 2$. U. C. Locality 672.
 Fig. 5b. *Glycimeris sagittatus* Gabb, $\times 2$. View showing hinge.
 Fig. 6a. *Glycimeris perrini*, n. sp., $\times 2$. Type.
 Fig. 6b. *Glycimeris perrini*, n. sp., $\times 2$. Hinge view of type.
 Fig. 6c. *Glycimeris perrini*, n. sp., $\times 2$. Young specimen, a cotype.
 Fig. 7. *Glycimeris fresnoensis*, n. sp., $\times 3$. Type.
 Fig. 8a. *Glycimeris hannibali*, n. sp., $\times 2$. Type.
 Fig. 8b. *Glycimeris hannibali*, n. sp., $\times 2$. Hinge view of type.
 Fig. 9a. *Crassatellites mathewsonii* (Gabb), $\times 2$. U. C. Locality 672.
 Fig. 9b. *Crassatellites mathewsonii* (Gabb), $\times 2$.
 Fig. 10. *Crassatellites lillisi*, n. sp., $\times 1$.
 Fig. 11. *Lucina (Myrtea) taffana*, n. sp., $\times 3$.
 Fig. 12. *Lucina packi*, n. sp., $\times 2$.



EXPLANATION OF PLATE 37

- Fig. 1a. *Lucina diegoensis*, n. sp., \times 1.
 Fig. 1b. *Lucina diegoensis*, n. sp., \times 1. Umbone view.
 Fig. 2a. *Venus aequilateralis* Gabb, \times 2.
 Fig. 2b. *Venus aequilateralis* Gabb, \times 2. Umbone view.
 Fig. 3. *Tellina jollaensis*, n. sp., \times 1.
 Fig. 4a. *Xenophora stocki*, n. sp., \times 1. Top view of type.
 Fig. 4b. *Xenophora stocki*, n. sp., \times 1. Side view.
 Fig. 5a. *Spiroglyphus(?) tejonensis* Arnold, \times 3. Bottom view.
 Fig. 5b. *Spiroglyphus(?) tejonensis* Arnold, \times 2. Top view.
 Fig. 6a. *Fasciolaria bilineata*, n. sp., \times 3. Back view of type specimen.
 Fig. 6b. *Fasciolaria bilineata*, n. sp., \times 3. Aperture view of cotype.
 Fig. 7. *Ficopsis cooperii* Gabb, \times 2. Aperture view of a cotype, a much better preserved specimen than Gabb's type.
 Fig. 8. *Turris fresnoensis* Arnold, \times 3. This specimen shows the form of canal better than Arnold's type.
 Fig. 9. *Surcula supraplanis* (Cooper), \times 1. Back view of a cotype. This species was placed in the genus *Fusus* by Cooper. Better preserved specimens show the sinus of the genus *Surcula*.
 Fig. 10. *Architectonica*, sp., \times 3. The figured specimen was found at University of California Locality 694.
 Fig. 11. *Odostomia packi*, n. sp., \times 3. Type specimen.
 Fig. 12. *Arca clarki*, n. sp., \times 3.
 Fig. 13. *Strepsidura howardi*, n. sp., \times 1.
 Fig. 14. *Perissolax gabbi*, n. sp., \times 1.



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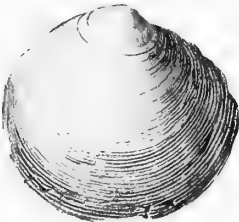
4a



5b



6a



1a



11



8



10



7



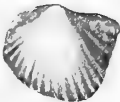
1b



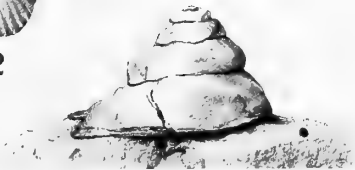
6b



9



12



4b



2a



2b



13



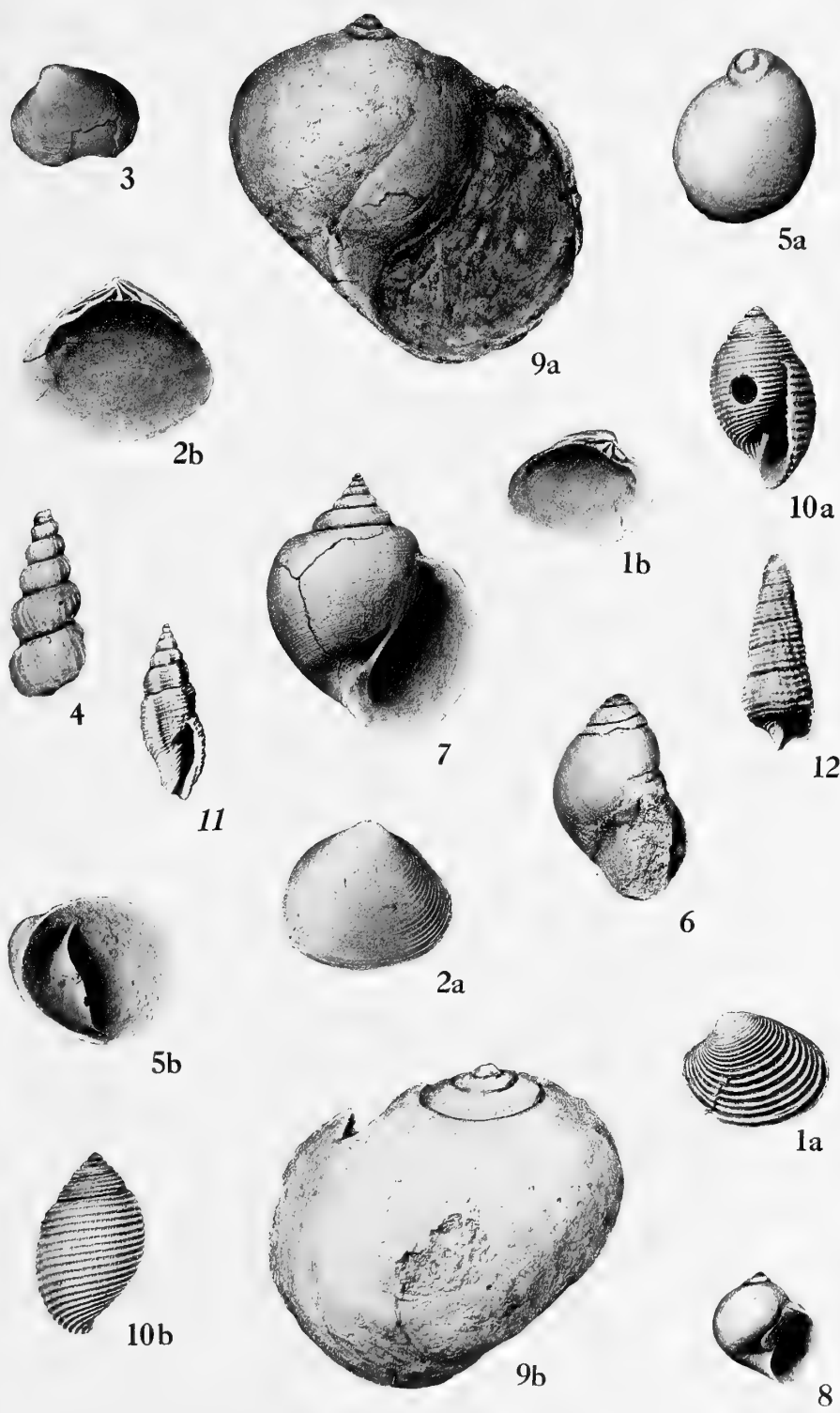
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5a

EXPLANATION OF PLATE 38

- Fig. 1a. *Meretrix hornii* Gabb, $\times 2$.
Fig. 1b. *Meretrix hornii* Gabb, $\times 2$. Showing hinge. U. C. Locality 672.
Fig. 2a. *Tivela packardi*, n. sp., $\times 2$.
Fig. 2b. *Tivela packardi*, n. sp., $\times 2$. View showing hinge. Cotype from U. C. Locality 672.
Fig. 3. *Marcia* (?) *conradi*, n. sp., $\times 2$. Type specimen.
Fig. 4. *Epitonium tejonensis*, n. sp., $\times 2$. Type.
Fig. 5a. *Crepidula inornata*, n. sp., $\times 3$.
Fig. 5b. *Crepidula inornata*, n. sp., $\times 3$. View showing deck.
Fig. 6. *Natica gesteri*, n. sp., $\times 2$.
Fig. 7. *Amauropsis alveata* (Conrad), $\times 2$. The young individual figured shows the fine spiral threads plainly. The umbilical chink is not so prominent in older individuals. U. C. Locality 672.
Fig. 8. *Natica uvasana* Gabb, $\times 1$.
Fig. 9a. *Natica hannibali* Dickerson, $\times 1$. This large specimen shows the peculiar callus on the inner lip better than the type. Specimen is from the Tejon group near Domengine Creek, Fresno County, Cal.
Fig. 9b. *Natica hannibali* Dickerson, $\times 1$. Back view of same specimen.
Fig. 10a. *Actaeon moodyi*, n. sp., $\times 2$. Aperture view of type. U. C. Locality 672. This form is also found at the type locality of the Tejon group.
Fig. 10b. *Actaeon moodyi*, n. sp., $\times 2$. Back view of type.
Fig. 11. *Mitramorpha parsoni*, n. sp., $\times 2$. Type specimen from U. C. Locality 672.
Fig. 12. *Cerithiopsis dumblei*, n. sp., $\times 3$.



EXPLANATION OF PLATE 39

Fig. 1. *Ostrea* cf. *appressa* Gabb, $\times 2$. From Tejon of Oroville South Table Mountain. U. C. Locality 2225.

Fig. 2a, 2b, 2c. *Spisula merriami* Packard, $\times 2$. Type and co-type from Tejon of Salt Creek about twenty miles north of Coalinga, U. C. Locality 672.

This is a very common species in the Tejon which ranges from the lowermost Tejon of the Mount Diablo region through the Upper or *Siphonalia sutterensis* zone. It was formerly identified as *Macra ashburneri* Gabb of the Chico Cretaceous.

Fig. 2d. *Spisula merriami* Packard $\times 2$.

This specimen was found at U. C. Locality 2225, Oroville South Table Mountain.

Fig. 3. *Acmaea ruckmani*, n. sp., $\times 3$. Type specimen from U. C. Locality 2225.

Fig. 4. *Lunatia nuciformis* Gabb, $\times 3$. This species occurs abundantly in both Marysville Buttes and Oroville Eocene strata. The specimen figured is from U. C. Locality 2225.

Fig 5a. *Neverita globosa* Gabb, $\times 3$. Aperture view, U. C. Locality 2225. A common species in the *Siphonalia sutterensis* zone.

Fig 5b. *Neverita globosa* Gabb, $\times 1$. Back view.

Fig. 6. *Neverita secta* Gabb, $\times 3$. This species ranges from the lowermost Tejon of the Mount Diablo region through the *Siphonalia sutterensis* zone.

Fig. 7. *Cerithiopsis orovillensis*, n. sp., $\times 3$. Type specimen U. C. Locality 2225.

Fig. 8. *Chrysodomus martini* Dickerson, $\times 2$. This was originally described as *Phos* (?) *martini* Dickerson. It is common at U. C. Locality 2225, South side Oroville South Table Mountain.

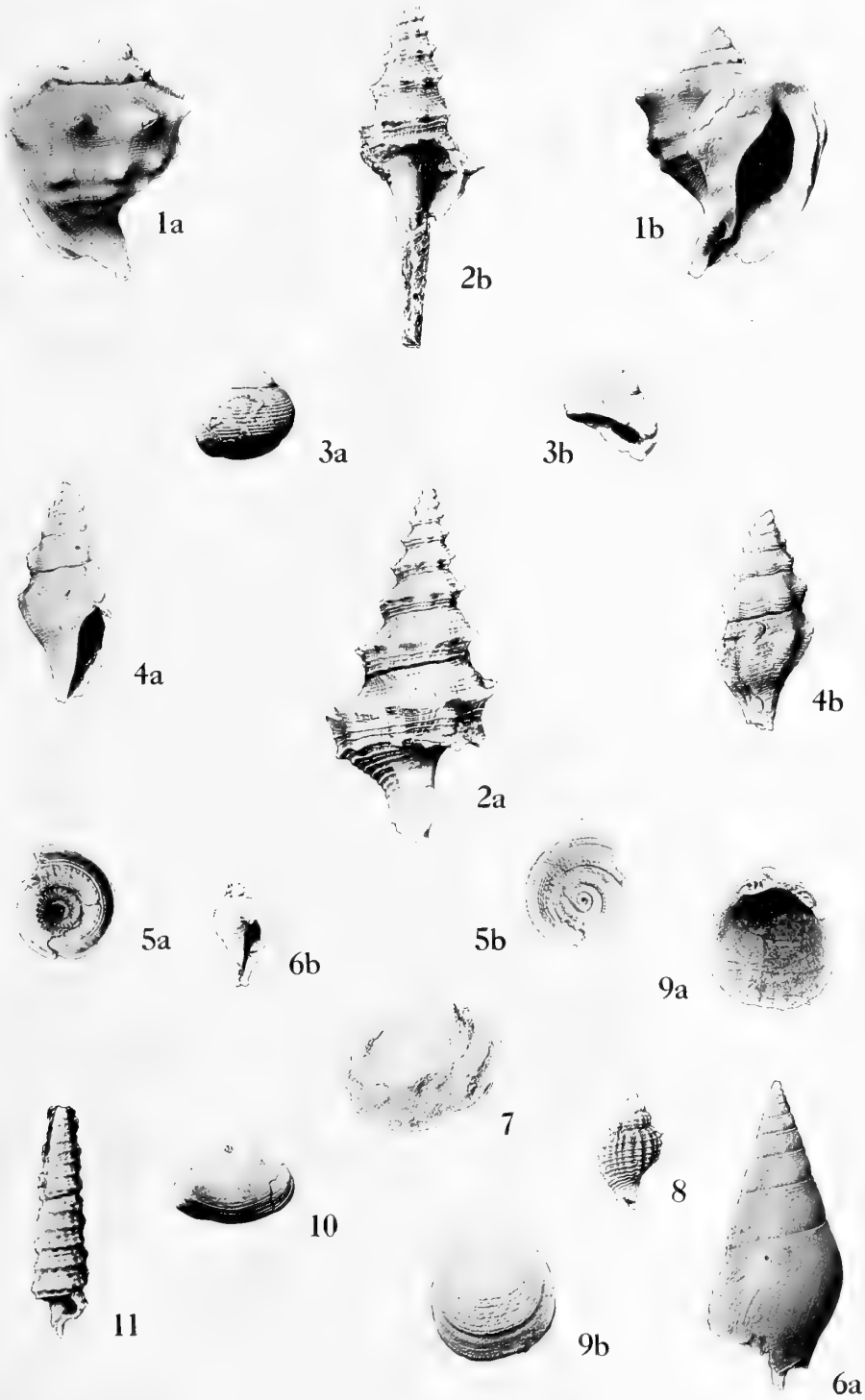
Fig. 9. *Cancellaria stantoni* Dickerson, $\times 3$. U. C. Locality 2225. A common species throughout the Tejon.

Fig. 10. *Turritella merriami* Dickerson, $\times 1$. U. C. Locality 2225. Range, throughout Tejon group.



EXPLANATION OF PLATE 40

- Fig. 1a. *Galeodea sutterensis*, n. sp., \times 1. Back view.
 Fig. 1b. *Galeodea sutterensis*, n. sp., \times 1. Mouth view.
 Fig. 2a. *Fusinus merriami*, n. sp., \times 2. Back view. University of California Locality 1853.
 Fig. 2b. *Fusinus merriami*, n. sp., \times 2. Mouth view. University of California Locality 1853.
 Fig. 3a. *Monodonta wattsi*, n. sp., \times 2. Back view of type specimen. U. C. Locality 1853. This species is also found in the Tejon of Washington.
 Fig. 3b. *Monodonta wattsi*, n. sp., \times 2. Mouth view of type specimen. U. C. Locality 1853.
 Fig. 4a. *Drillia ullreyana* Cooper, \times 2. Mouth view. U. C. Locality 1853. This species is generally found somewhat eroded. The specimen figured shows less rounded nodes than Cooper's type and the threads below the whorl are much stronger owing to better preservation.
 Fig. 4b. *Drillia ullreyana* Cooper, \times 2. Back view of specimen figured as 4a. U. C. Locality 1853.
 Fig. 5a. *Architectonica ullreyana*, n. sp., \times 3. View of base. U. C. Locality 1853.
 Fig. 5b. *Architectonica ullreyana*, n. sp., \times 3. Top view.
 Fig. 6a. *Drillia cooperi*, n. sp., \times 1. Back view of type specimen.
 Fig. 6b. *Drillia cooperi*, n. sp., \times 1. Mouth view of a small specimen. U. C. Locality 1853. This species also occurs in the Tejon near Lower Lake, Lake County, California.
 Fig. 7. *Ostrea*, cf. *aviculaformis* Anderson, \times 3. U. C. Locality 1853.
 Fig. 8. *Nyctilochus californicus* (Gabb), \times 3. U. C. Locality 1853. The specimen figured is a young individual. Formerly known as *Tritonium californicum*.
 Fig. 9a. *Glycimeris marysvillensis* Dickerson, \times 3. U. C. Locality 1853.
 Fig. 9b. *Glycimeris marysvillensis* Dickerson, \times 3. This specimen is higher than the type, which was a young specimen.
 Fig. 10. *Corbula parilis* Gabb, \times 2. U. C. Locality 1853. This is a very common Tejon form.
 Fig. 11. *Bittium longissimum* Cooper, \times 3. This beautiful species is the only one known besides the type, both of which came from U. C. Locality 1853.



EXPLANATION OF PLATE 41

Fig. 1a. *Surcula clarki* Dickerson, $\times 3$. U. C. Locality 2225, south side Oroville South Table Mountain. This specimen is a mature form.

Fig. 1b. *Surcula clarki* Dickerson $\times 3$. U. C. Locality 2225. Young specimen.

Fig. 2. *Turris inconstans* (Cooper), $\times 2$. U. C. Locality 2225. An upper Tejon species.

Fig. 3a. *Turris monolifera* (Cooper), $\times 3$. Young specimen from U. C. Locality 2225.

Fig. 3b. *Turris monolifera* (Cooper), a mature form from U. C. Locality 2225.

Fig. 4. *Drillia orovillensis*, n. sp., $\times 3$. Type from U. C. Locality 2225. Aperture view.

Figs. 5a, 5b, 5c, 5d, 5e. *Siphonalia sutterensis* Dickerson, U. C. Locality 2225. This is an abundant and characteristic species of the uppermost zone thus far recognized in the Tejon group of California. The series illustrates the variation in form with increase in age. 5a, $\times 2$; 5b, $\times 2$; 5c, $\times 1$; 5e $\times 1$.

Fig. 6a. *Nyctilochus diegoensis* (Gabb), $\times 2$. U. C. Locality 2225. Back view.

Fig. 6b. *Nyctilochus diegoensis* (Gabb), $\times 2$. U. C. Locality 2225. Aperture view.

Fig. 6c. *Nyctilochus diegoensis* (Gabb), $\times 2$. Back view. This species was described from the Tejon of Rose Cañon, San Diego Quadrangle, from a horizon which is probably 300 or 400 feet above the base of the Tejon at this point. It is not a common species. Range, Lower or Middle Tejon through *Siphonalia sutterensis* zone.

Fig. 7a. *Ocenebra nashi*, n. sp., $\times 2$. Type from U. C. Locality 2225. Aperture view.

Fig. 7b. *Ocenebra nashi*, n. sp. $\times 2$. Back view.

Fig. 8a. *Nyctilochus thunani*, n. sp., $\times 2$. Type from U. C. Locality 2225. Back view.

Fig. 8b. *Nyctilochus thunani*, n. sp., $\times 3$. Co-type from U. C. Locality 2225. Aperture view.

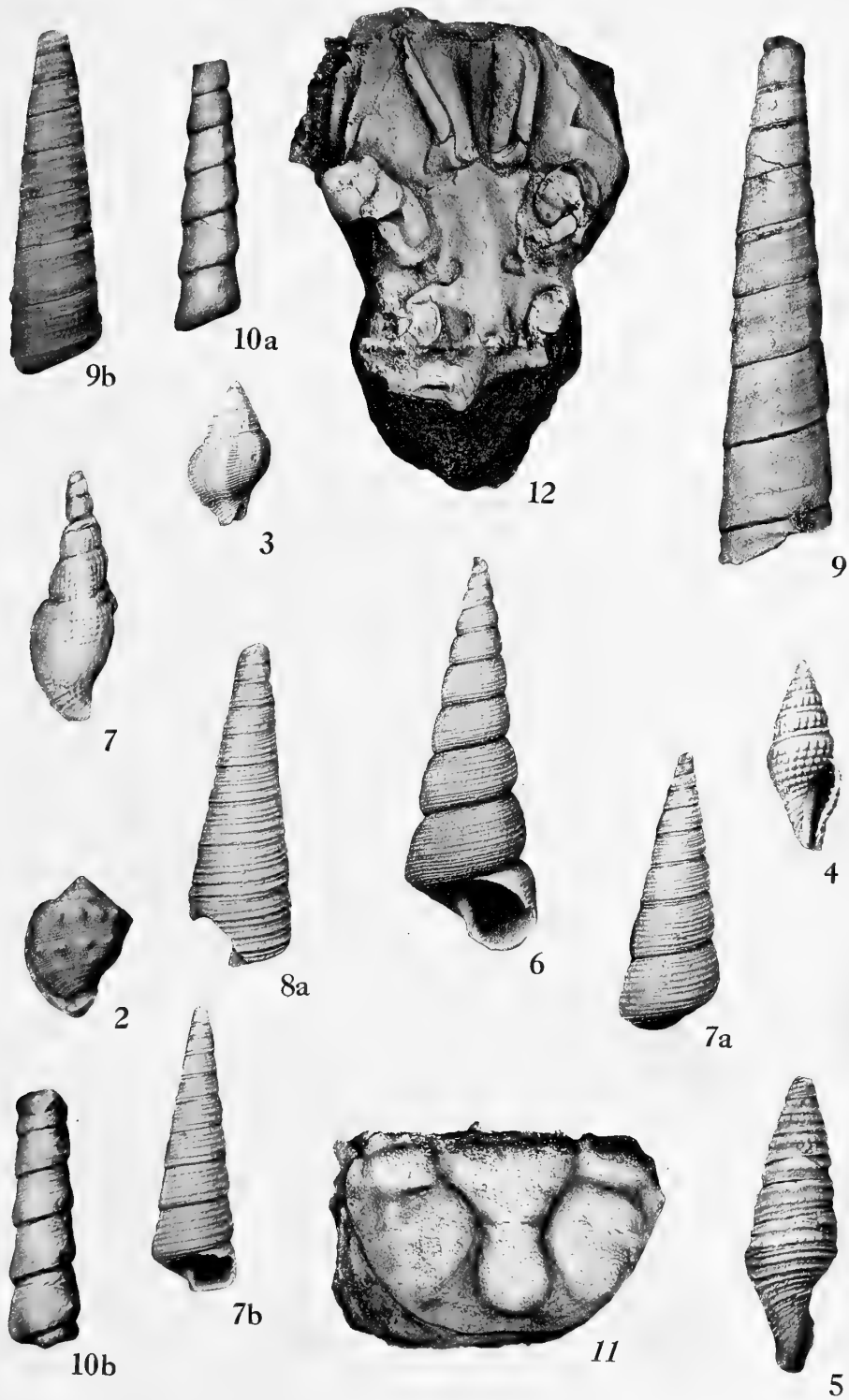
Fig. 9. *Nyctilochus whitneyi* Gabb, $\times 2$. U. C. Locality 1853. Tejon Eocene of Marysville Buttes. This is introduced for comparison with *N. thunani*, n. sp. Aperture view.





EXPLANATION OF PLATE 42

- Fig. 1. *Metula harrisi*, n. sp., $\times 2$.
- Fig. 2. *Galeodea tuberculata* (Gabb), $\times 1$. This species sometimes has only two rows of tubercules. The third is feebly developed in this specimen.
- Fig. 3. *Nyctilochus hornii* (Gabb), $\times 2$. U. C. Locality 672.
- Fig. 4. *Surcula gesteri*, n. sp., $\times 3$. Type specimen from Univ. of Cal. Locality 672. This species also occurs at the type locality of the Tejon group and in the Cowlitz phase of the Washington Tejon.
- Fig. 5. *Turris stocki*, n. sp., $\times 2$.
- Fig. 6. *Turritella uvasana* Conrad, $\times 2$. Specimen from U. C. Locality 672.
- Fig. 7a. *Turritella buwaldana*, n. sp., $\times 2$. Back view of type specimen.
- Fig. 7b. *Turritella buwaldana*, n. sp., $\times 2$. Aperture view of type.
- Fig. 8. *Turritella kawi*, n. sp., $\times 2$.
- Fig. 9a. *Turritella andersoni*, n. sp., $\times 3$. Type specimen.
- Fig. 9b. *Turritella andersoni*, n. sp., $\times 3$. Variety which is spirally ribbed.
- Fig. 10a. *Turritella lawsoni*, n. sp., $\times 2$. U. C. Locality 2295.
- Fig. 10b. *Turritella lawsoni*, n. sp., $\times 2$. Specimen which shows decoration of medial whorls well.
- Fig. 11. *Cancer(?)*, sp. a. U. C. Locality 1817.
- Fig. 12. *Cancer(?)*, sp. b. A common but poorly preserved form from U. C. Locality 1817.





EXPLANATION OF PLATE 43

Fig. 1. East end of South Table Mountain on right, Table Mountain in distance and Morris Ravine between the two buttes.

Fig. 2. Looking west along south side of South Table Mountain. Bench gravels in foreground. Tejon Eocene capped by Older Basalt in center.



FIG. 1



FIG. 2

EXPLANATION OF PLATE 44

Fig. 1. Looking north at Planicosta Butte, a plateau remnant a mile south of Merced Falls. Steeply inclined Mariposa slates are seen in the foreground. The hill is capped by coarse sandstone which yielded an abundance of *Venericardia planicosta merriami*.

Fig. 2. Clays of the Ione formation along the Merced River one mile southwest of Merced Falls capped by a stratum of andesitic tuff breccia. These clay beds are stratigraphically below the sandstones of Planicosta Butte shown in the figure above.

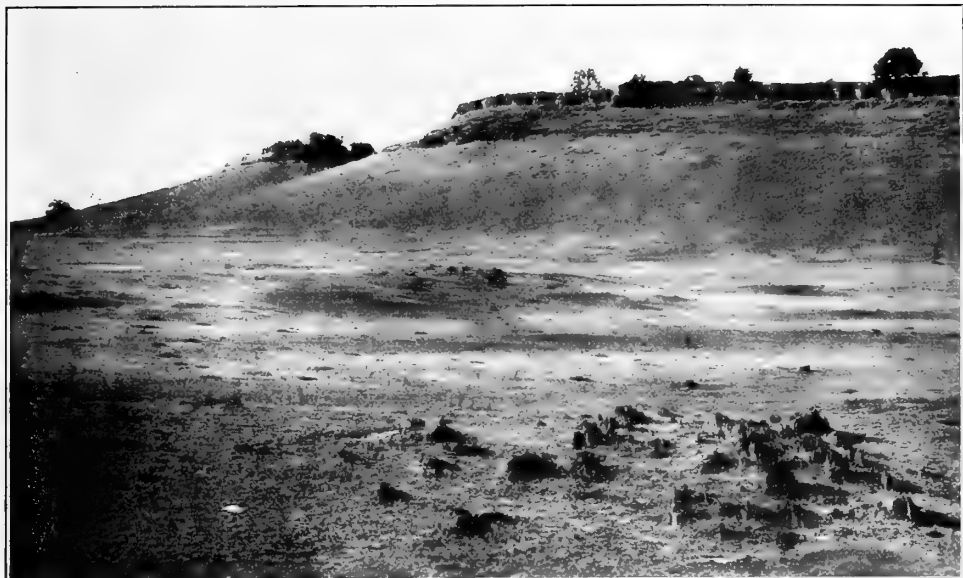


FIG. 1

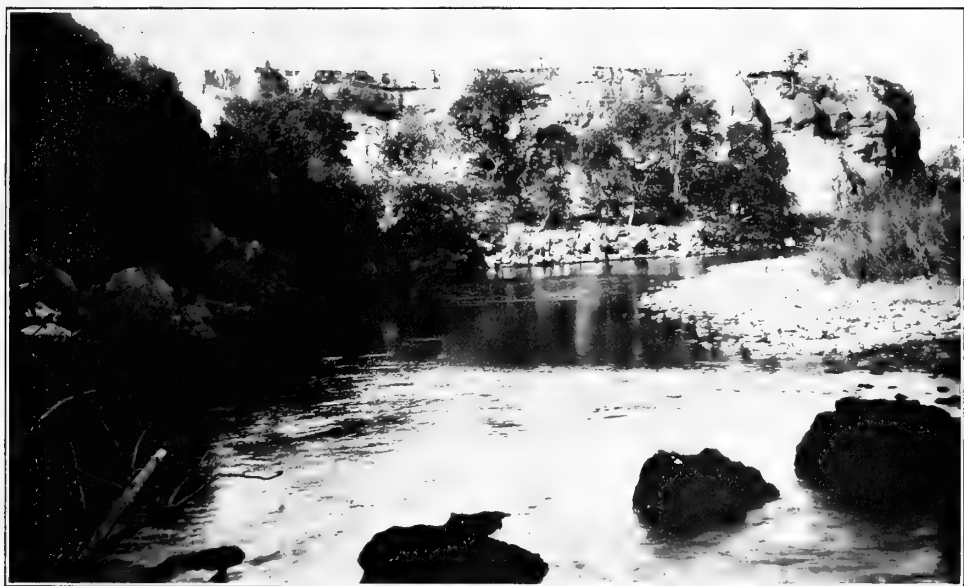


FIG. 2

EXPLANATION OF PLATE 45

Fig. 1. A view of the Marysville Buttes from Sutter City looking northwest. This picture shows the buttes rising above the level floor of the Sacramento Valley. South Butte is the highest peak on the extreme left.

Fig. 2. A near view of South Butte taken from the divide on the road between Sutter City and the town of West Butte. The rounded hills in the foreground have been formed from the soft tuffs of the Sutter formation.



FIG. 1

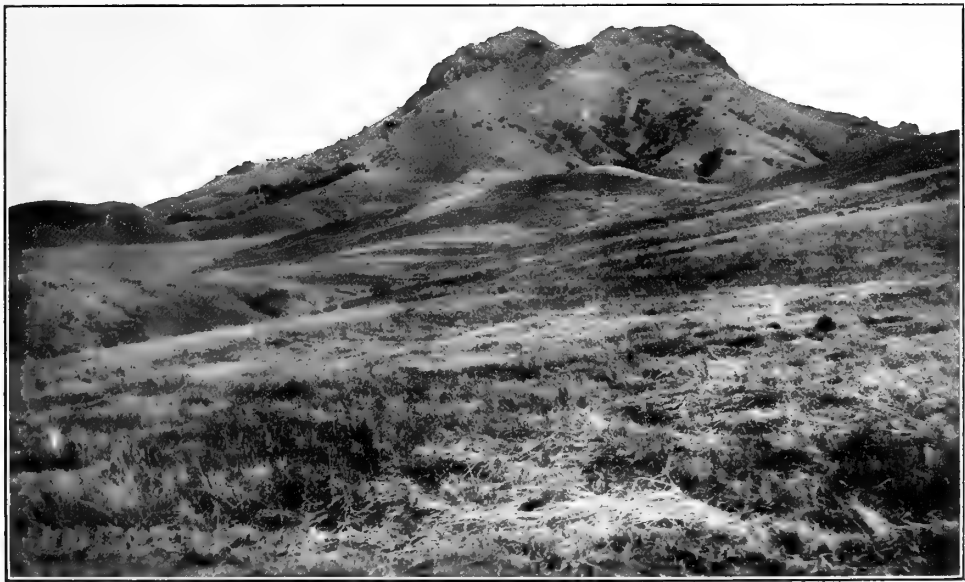


FIG. 2

EXPLANATION OF PLATE 46

Fig. 1. Looking west from the divide in the "Pass" on road between Sutter City and West Butte. The "Pass" is cut in the soft tufts of the Sutter formation. The hills in the middle ground are composed of the Sutter formation and possibly Tejon and Chico strata also occur here. The hill on the right is a rhyolitic neck. The slope of the outer rim of the andesitic lava flow is seen in the hill on the left.

Fig. 2. A view showing the geological relations of the Sutter formation to the overlying andesitic lava flow and the underlying Chico. West Butte is the high peak on the right. The peak in the center is a rhyolitic neck surrounded on all sides by the Sutter formation. The even sky-line on the left is due to the gently dipping andesitic lava flow, the outer rim of the old volcano. The steeply dipping westward strata on the left are Chico rocks and their mantling cover is the tufts of the Sutter formation which in the hill just west of West Butte dip ten degrees west. The Tejon shales outcrop at a point to the left of the picture.

*



FIG. 1



FIG. 2

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RELATIONSHIP OF EQUUS TO PLIOHIPPIUS
SUGGESTED BY CHARACTERS OF A NEW
SPECIES FROM THE PLIOCENE
OF CALIFORNIA

BY

JOHN C. MERRIAM

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RELATIONSHIP OF EQUUS TO PLIOHIPPIUS SUGGESTED BY CHARACTERS OF A NEW SPECIES FROM THE PLIOCENE OF CALIFORNIA

BY

JOHN C. MERRIAM

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INTRODUCTION

Recent studies of late Cenozoic Equidae¹ from the Pacific Coast province of the United States have shown the existence of a California Pliocene horse exhibiting advanced characters in some respects intermediate between those of typical *Equus* and typical *Plihippus*. As considerable uncertainty has existed concerning the immediate ancestry of *Equus*, any evidence furnished by the new California form is of special significance, and should therefore be presented in detail for use in studies on the evolution of this group. It seems particularly desirable to make available significant new materials received since the last published reference to this peculiar form.

The studies on West Coast Equidae leading to the statement in the following article have been greatly facilitated by cordial co-operation of Professor Henry F. Osborn and Doctor William D. Matthew of the American Museum of Natural History. Through courtesies extended in the use of collections and of organized studies made by the Museum,

¹ Merriam, J. C., Trans. Amer. Phil. Soc., n. s., vol. 22, part 3, p. 33, 1915; also Univ. Calif. Publ. Bull. Dept. Geol., vol. 9, p. 56, 1915.

it has been possible to reach interpretations of new Pacific Coast collections which would otherwise have been attained with difficulty. Material assistance in study of the *Pliohippus* group was also given by Professor Richard S. Lull of Yale University through preparation of excellent casts representing the dentition and feet of the type specimen of *Pliohippus pernix*. It is with pleasure that the writer acknowledges the co-operation of those who have contributed to the furtherance of this and of other related investigations. It is presumably not an exaggeration to state that, at this stage in the advance of science, there can be little hope of material progress in new work without such co-operation as tends to make the individual investigator merely one among many assisting in the advance movement in a given direction.

PLIOHIPPIUS PROVERSUS, n. sp.

Equus or *Pliohippus*, sp. Merriam, J. C., Trans. Amer. Phil. Soc., n. s., vol. 22, part 3, p. 33, 1915.

Equus or *Pliohippus*, probably new. Merriam, J. C., Univ. Calif. Publ. Bull. Dept. Geol., vol. 9, p. 56, 1915.

Type specimen an upper cheek-tooth, M¹ or M², no. 21330, from the upper portion of the Etchegoin formation, locality 2079, North Coalinga region, western border of the San Joaquin Valley, California.

Cheek-teeth large, long-crowned, heavily cemented. Upper cheek-teeth slightly curved; mesostyle heavy; fossettes wide to narrow, with moderately crinkled enamel borders; protocone large, strongly compressed laterally in the molars, inner border convex or nearly flat. Lower cheek-teeth with short or long parastylid; metaconid-metastylid column commonly long anteroposteriorly and narrow transversely, inner groove wide, flat as in *Equus*, or somewhat narrowed tending toward the angular form seen in *Pliohippus*; outer faces of protoconid and hypoconid either convex or somewhat flattened.

Limb elements, so far as known, much like those of *Equus*. Unciform facet of metacarpal III sloping away from the plane of the magnum at approximately the angle shown in *Equus*. Lateral digits apparently much reduced distally and feet presumably monodactyle.

As indicated in earlier publications,² the advanced equid of the upper Etchegoin finds its nearest American relatives in *Equus* (*Pliohippus*) *simplicidens*³ and *Equus* (*Pliohippus*) *cumminsii* of the Blanco Pliocene in Texas. Like the California species the two Texas forms are known by very imperfect material in which the lower dentition furnishes the better representation. The Blanco species were considered by Cope⁴ to represent ancient types of the *Equus* group with

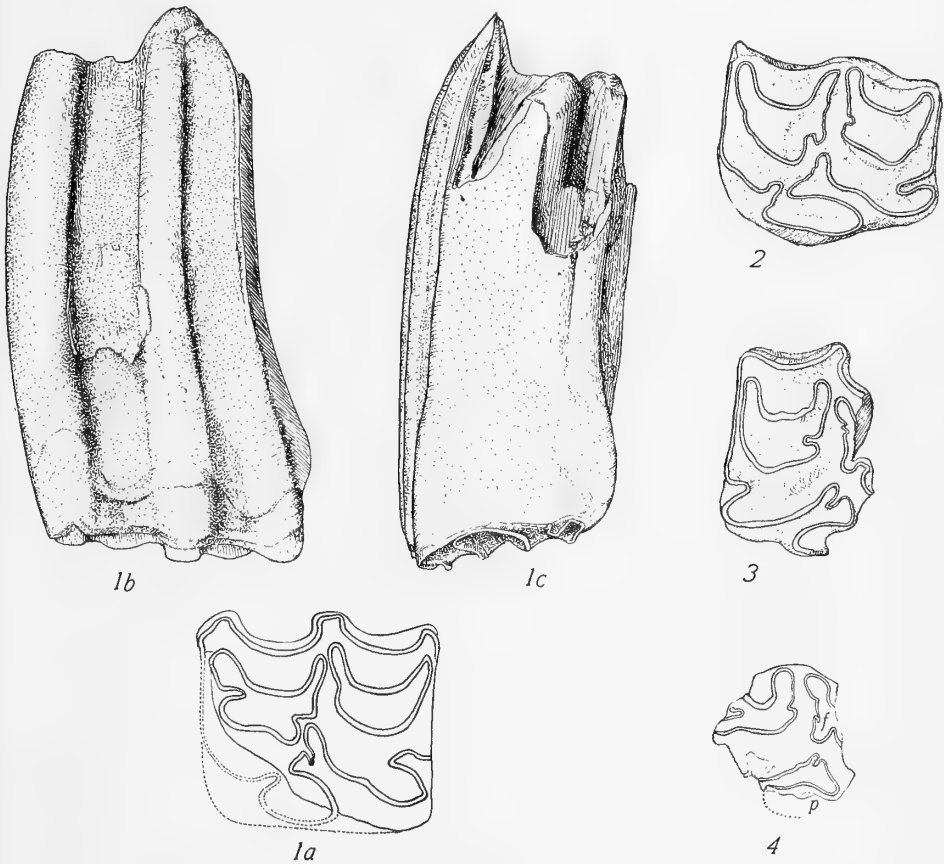
² Merriam, J. C., *op. cit.*, 1915.

³ Referred to *Equus* by E. D. Cope (Geol. Surv. Texas, 4th Ann. Rep. for 1893, p. 66); but considered as *Pliohippus* by J. W. Gidley (Bull. Amer. Mus. Nat. Hist., vol. 14, p. 123, 1901).

⁴ Cope, E. D., Proc. Amer. Phil. Soc., vol. 30, p. 125, 1892.

relatively simple characters. It is interesting to note in this connection that the peculiar characters of Cope's *Equus simplicidens* furnished some of the most important evidence used in determining the age of the Blanco beds.

The upper cheek-teeth of *P. proversus* (figs 1a to 4), as well as of the *P. simplicidens* and *P. cumminsii* types, are distinguished from those of *Pliohippus* as represented in the typical form, *P. pernix*, by straighter crowns, with heavier mesostyle; tendency to narrowing of



Figs. 1a to 4. *Pliohippus proversus*, n. sp. From the upper Etchegoin Pliocene of the North Coalinga region, California. Figures approximately natural size.

Figs. 1a, 1b, and 1c. $P^3?$, no. 22328; fig. 1a, occlusal view; fig. 1b, outer view; fig. 1c, posterior view.

Fig. 2. M^1 or M^2 , no. 21330, type specimen, occlusal view.

Fig. 3. $P^3?$, no. 21331, occlusal view.

Fig. 4. Portion of an upper cheek-tooth, no. 22329, occlusal view; *p*, protocone; *f*, prefossette.

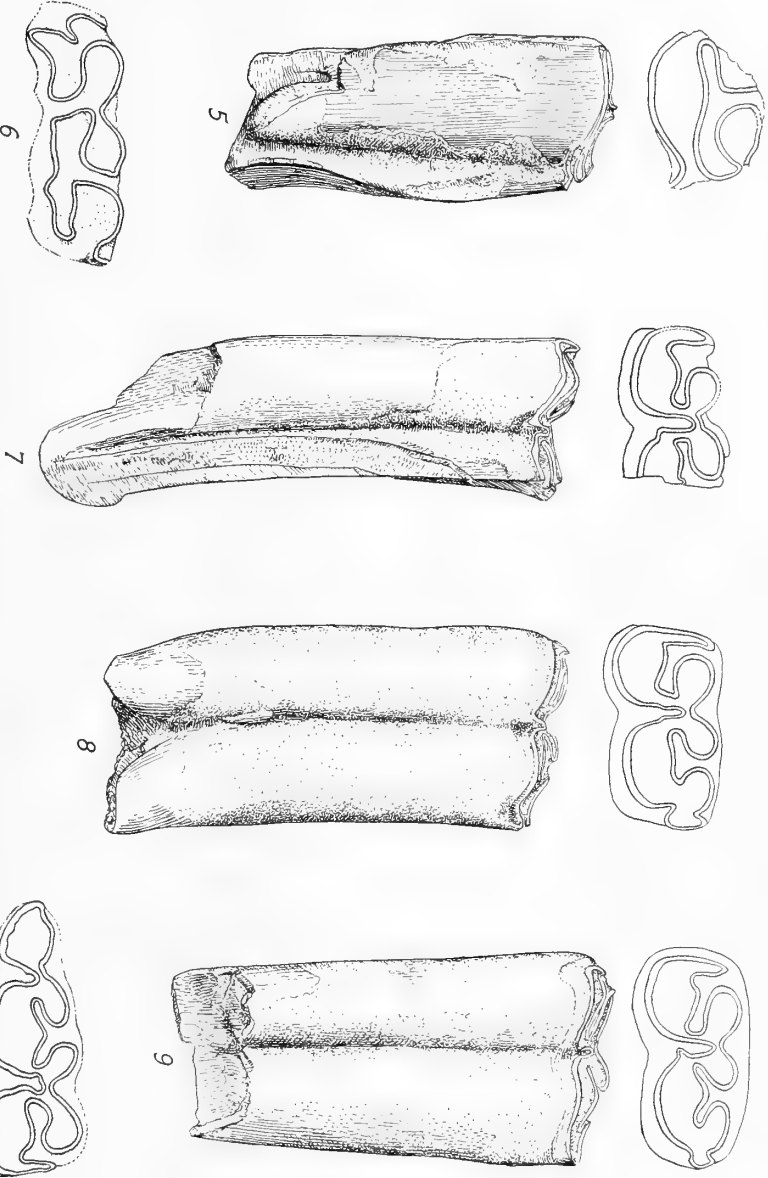
the fossettes; and especially by the form of the protocone. In typical *Pliohippus* the protocone is nearly circular in cross-section in the premolars, but tends to flatten toward the posterior end of the molar series. In the *P. proversus* type the protocone is relatively wide transversely in the premolar region, but is flatter or narrower transversely in all of the cheek-teeth than in *P. pernix*.

The upper cheek-teeth in *P. proversus* and in the other members of this group are distinguished from those of *Equus* especially by the form of protocone (see figs. 13 to 16). In typical *Equus* this pillar is normally longer anteroposteriorly, flatter transversely, reaches farther forward in advance of the isthmus connecting it with the protoconule, and is concave rather than convex on the inner side. There is also in *Equus* a stronger tendency to flattening of the outer faces of the paracone and metacone, the mesostyle inclines to be thicker, and the fossettes are usually narrower and have more strongly folded walls. In *E. stenonis* of the Old World and in *E. occidentalis* of California, the distinctive characters separating *Equus* from the *P. proversus* group are largely reduced in value. The form of protocone in *E. stenonis* may approach that of typical *Pliohippus* in nearly all characters, as it often tends to do in the milk dentition of modern *Equus*. In *E. occidentalis* the protocone is commonly short anteroposteriorly and may be nearly as *Pliohippus*-like as in the known *P. proversus* specimens. Both in *E. stenonis* and *E. occidentalis* the combination of all characters present in any given tooth is, however, commonly such as to indicate closer relation to modern *Equus* forms than to the *P. proversus* group.

The lower cheek-teeth of the upper Etchegoin *P. proversus* resemble those of a series described by Cope from the Blanco Pliocene of Texas, and referred to *P. simplicidens*. The Blanco teeth (fig. 17) are characterized by their considerable size, heavy cementation, and by the anteroposterior length of the metaconid-metastylid column. The metaconid-metastylid column commonly shows a rather sharply angular internal groove. Cope⁵ considered the character of this column distinctive of *P. simplicidens*, in contrast with the *Equus* forms of the Pleistocene. In *P. simplicidens* the outer walls of the protoconid and hypoconid are convex to flattened.

In the lower teeth of the *P. proversus* type from the upper Etchegoin the crowns are large, long, and heavily cemented. The metaconid-metastylid column in a number of specimens (figs. 5, 6, and 7) is wide

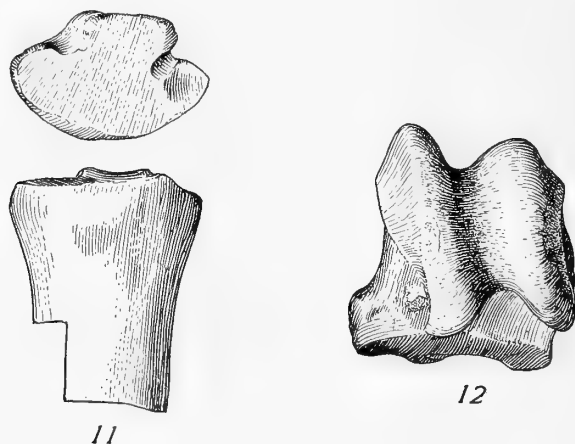
⁵ Cope, E. D., Geol. Surv. Texas, 4th Ann. Rep. for 1893, p. 66.



Figs. 5 to 10. *Pliohippus provetus*, n. sp. Upper Eocene, Pioche, North Coalinga, California. Figures natural size.
 Fig. 5. Inferior cheek-tooth, no. 22316, outer and occlusal views.
 Fig. 6. I_1 , no. 21332, occlusal view.
 Fig. 7. Inferior molar, no. 22330, outer and occlusal views.
 Fig. 8. M_1 , no. 22312, outer and occlusal views.
 Fig. 9. M_2 , no. 22314, outer and occlusal views.
 Fig. 10. M_3 , no. 21333, occlusal view.

anteroposteriorly and the internal groove is broad and flat. The width and flatness of the groove sometimes considerably exceed that in the simpler variations of *Equus*. In other lower cheek-teeth from the upper Etchegoin (figs. 8, 9, and 10) the inner groove of the metaconid-metastylid column is sharper than in *Equus* and more nearly resembles that in typical *Pliohippus*.

The form of the lower cheek-teeth in *P. proversus* is close to that of the Blanco material referred by Cope to *P. simplicidens*. The two types may be specifically different, but they apparently represent a group, which, as is shown in the upper cheek-teeth, appears separable from *Equus*, and does not correspond closely to typical *Pliohippus*.



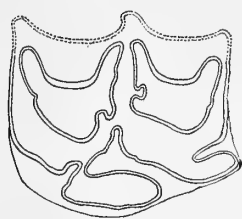
Figs. 11 and 12. *Pliohippus proversus*, n. sp. From the upper Etchegoin Pliocene of the North Coalinga region, California. Both figures one-half natural size.

Fig. 11. Left metacarpal III, no. 22318, anterior and proximal views.

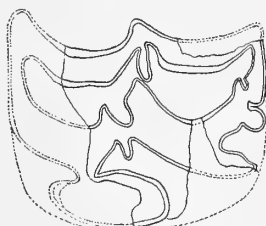
Fig. 12. Astragalus, no. 22334.

RELATIONSHIPS

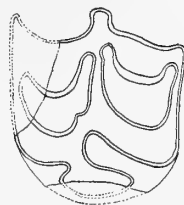
The horses referred to the *Pliohippus proversus* type from the upper Etchegoin Pliocene of California are distinct from all of the most advanced horses of the lower Etchegoin and Ricardo Pliocene stages of the Pacific Coast province. There is, however, in certain characters sufficiently close resemblance to some of the Ricardo species to suggest that the upper Etchegoin form may be derived by modification from one of the early Pliocene Pacific Coast species near *Pliohippus tantalus* or *P. fairbanksi*.



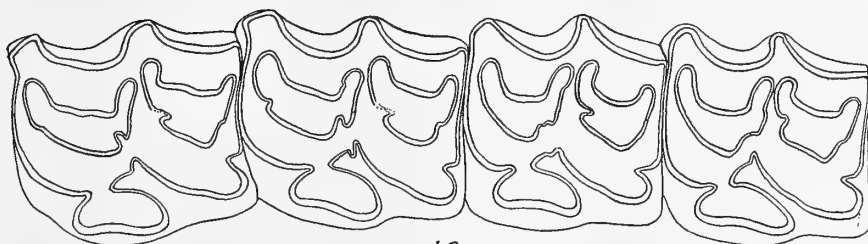
13



14



15



16



17



18

Fig. 13. *Pliohippus proversus*, n. sp. M^1 or M^2 , type specimen, no. 21330, natural size. Upper Etchegoin, North Coalinga region, California.

Fig. 14. *Pliohippus simplicidens* (Cope). Superior premolar?, natural size, Blanco Pliocene, Texas. (After Cope.) The inner single dotted line in reconstruction of the protocone represents the writer's interpretation of this pillar.

Fig. 15. *Pliohippus cumminsii* (Cope). Superior molar, natural size. Blanco Pliocene, Texas. (After Cope.)

Fig. 16. *Equus occidentalis* Leidy. P^3 to M^2 , no. 21001, natural size. Pleistocene, Rancho La Brea, California.

Fig. 17. *Pliohippus* referred to *simplicidens* (Cope). Lower cheek-tooth series, one-half natural size. Blanco Pliocene, Texas. (After Cope.)

Fig. 18. *Equus occidentalis* Leidy. Lower cheek-tooth series, no. 12269, one-half natural size. Pleistocene, Rancho La Brea, California.

In considering the relation of *P. proversus* to forms of American faunas later than the upper Etchegoin, it is interesting to note that *Equus occidentalis* of the California Pleistocene represents the North American species of *Equus* in which the characters of the cheek-teeth show greatest simplicity. The gap between *P. proversus* and *E. occidentalis* is too wide to permit the conclusion that the later of the two is derived immediately from the earlier (see figs 1a to 10, 13, 16, and 18). In this connection it should be noted that the upper Etchegoin stage, in which *P. proversus* occurs, is separated from the Pleistocene horizon containing *E. occidentalis* by the Tulare formation, representing a thickness estimated by Arnold and Anderson⁶ to include at least three thousand feet of strata.

Of the Old World forms later than the upper Etchegoin stage of the Pliocene, the type most nearly approaching *P. proversus* is *Equus stenonis*,⁷ described from the Pliocene and Pleistocene, and representing the least progressive Old World type of the genus *Equus*. In some respects *E. stenonis* approaches the *P. proversus* type more closely than does the American *E. occidentalis*. This may be due to the origin of *E. stenonis* either in America or in Eurasia at a time earlier than the Pleistocene stage of *E. occidentalis*. The Tulare formation of California represents such a time in the geologic sequence. The fauna of the Tulare is as yet very imperfectly known, and no horse remains have been reported from these beds. It is probable that a stage less advanced than *E. occidentalis* and more progressive than *P. proversus* will yet be obtained from the Tulare section.

The similarity in general characters of *Pliohippus proversus* of the upper Etchegoin to the two *Pliohippus* species of the Blanco Pliocene, considered with similarity of the vertebrate faunas of the Blanco and upper Etchegoin leaves little room for doubt that *P. proversus*, *P. simplicidens*, and *P. cumminsii* represent closely allied forms of nearly the same epoch. In the characters of both upper and lower cheek-teeth the forms of this group are intermediate between typical *Pliohippus* and typical *Equus*, and represent the nearest approach to the *Equus* type found among American Tertiary horses. The geologic occurrence of these species represents a stage following the time of maximum development of *Pliohippus* and apparently preceding the earliest known occurrence of true *Equus*. The evidence presented in this sequence of horse types in America indicates that some, at least,

⁶ Arnold, Ralph & Anderson, Robert, U. S. Geol. Surv. Bull. 398, p. 147, 1910.

⁷ See Major, Forsyth, C. J., Abhl. Schw. Palae. Ges., vol. 4, Taf. 1 and 2, 1877; also *ibid.*, vol. 7, Taf. 7, 1880.

of the *Equus* forms of this continent were derived from *Pliohippus* along a line of evolution passing through or near the *P. proversus* group.⁸ Whether, as has been held by several writers, certain Old World forms included in *Equus* had an independent origin by way of *Hipparion*, may still be a field for discussion. *Equus sivalensis* and *E. namadicus* reported from the uppermost Siwalik beds of India,⁹ are held to represent true *Equus*, and have been considered as possible derivatives from *Hipparion*. Much remains to be known concerning the characters of these forms, as also concerning their exact occurrence in the geologic scale. Should the uppermost Siwalik fauna containing species referred to *Equus* prove to be late Pliocene there would seem to be abundant opportunity for origin of the Indian forms from an American type of the geologic stage represented by *P. proversus*, as the upper Etchegoin beds lie below the great Tulare section, which has been presumed to be mainly, if not entirely, Pliocene.

⁸ The line of evolution from *Pliohippus* to *Equus* has been recognized by many writers, although the stages of transition have not been fully indicated.

⁹ See Lydekker, Richard, *Palaeontologia Indica*, ser. 10, vol. 2, part 3, pp. 21 to 30, pls. 14 and 15, 1882; also Pilgrim, Guy E., *Records Geol. Surv. India*, vol. 43, part 4, p. 324, 1913.

MEASUREMENTS

	P. simpli- cidens	P. cum- minsii	P. pro- versus No. 22328	E. occi- dentalis No. 21001
P ³ , anteroposterior diameter .....	.....	.....	33 mm.	30.4
P ³ , transverse diameter .....	.....	.....	28.5	28.2
P ³ , anteroposterior diameter of protocone..	.....	.....	a10.7	11.9
			No. 21331	
P ⁴ , anteroposterior diameter a31 mm.	.....	.....	.....	30.2
P ⁴ , transverse diameter a27	.....	.....	29	28.4
P ⁴ , anteroposterior diameter of protocone..	a12	.....	a10.2	12
			No. 10921330	
M ¹ , anteroposterior diameter .....	.....	22	30	26.3
M ¹ , transverse diameter .....	.....	a25.5	a27	27.1
M ¹ , anteroposterior diameter of protocone..	.....	9.5	13.8	11.1
M ² , anteroposterior diameter .....	.....	.....	.....	27.5
M ² , transverse diameter .....	.....	.....	.....	26.8
M ² , anteroposterior diameter of protocone..	.....	.....	.....	12.8
			No. 12269	
P ₂ , anteroposterior diameter 39	.....	.....	.....	34
P ₂ , transverse diameter 16.5	.....	.....	.....	17.8
P ₂ , anteroposterior diameter of metaconid- metastylid column	16.5	.....	.....	15.9
P ₃ , anteroposterior diameter 33.6	.....	.....	.....	29.8
P ₃ , transverse diameter 17	.....	.....	.....	17
P ₃ , anteroposterior diameter of metaconid- metastylid column	20	.....	.....	18.3
			No. 21332	
P ₄ , anteroposterior diameter 33	.....	.....	34.1	29.5
P ₄ , transverse diameter 17	.....	.....	.....	18.2
P ₄ , anteroposterior diameter of metaconid- metastylid column	20	.....	17.7	17.7
			No. 21333	
M ₁ , anteroposterior diameter 32	.....	.....	27.5	26
M ₁ , transverse diameter 15.5	.....	.....	.....	17
M ₁ , anteroposterior diameter of metaconid- metastylid column	16.5	.....	.....	13.9
			No. 22314	
M ₂ , anteroposterior diameter 31	.....	.....	27	27
M ₂ , transverse diameter 15.8	.....	.....	12.8	17.3
M ₂ , anteroposterior diameter of metaconid- metastylid column	17	.....	13.6	14.8
			No. 21333	
M ₃ , anteroposterior diameter 37	.....	.....	36.2	31.5
M ₃ , transverse diameter 14.1	.....	.....	13.8	16
M ₃ , anteroposterior diameter of metaconid- metastylid column	16.5	14.7	13.4

a, approximate.

¹⁰ M¹ or M².

Transmitted March 14, 1916.

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are printed in a **bold-faced** type.

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